Anyone can make accurate SOUND LEVEL TESTS...

...with this dependable, portable

Western Electric

Sound Level Meter

THIS instrument—available in a-c line or battery operated models—is small and light, simple to operate, ruggedly built, adaptable to many noise measuring problems. And it's modestly priced!

The Western Electric Sound Level Meter has built-in calibration circuits to permit rapid, accurate adjustment to A.S.A. standard reference levels. Negative feedback in the amplifier contributes to utmost stability.

The frequency range of this meter is 20 to 10,000 cps. It can be used alone—or in conjunction with an associated Filter Set which enables the meter to measure sound in selected frequency bands between 50 and 4800 cycles.

Send the coupon at right or call your Graybar Representative for full information.

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Please send me Bulletin T-2260B describing Western Electric Sound Level Meters and Noise Analyzers.

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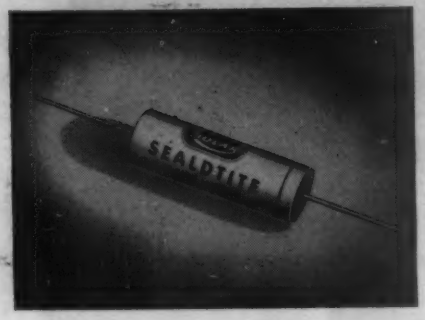
The Solar System
electronics edition • March 1948

ALL-PURPOSE HI-TEMP SEALDTITE* TUBULARS



Sealdtite Capacitors, the molded tubulars first pioneered by Solar in 1939, are now truly all-purpose capacitors. The recent introduction of a new Hi-Temp molded jacket makes Sealdtite Capacitors a universal choice for both automobile and home radio applications.

More than a year's field trials of well over 5,000,000 Hi-Temp molded Sealdtites in automobile and export receiver applications have proven the superior quality of this latest Solar development in the capacitor art.

Securely sealed against atmospheric moisture by a tough molded armor, Sealdtite Capacitors maintain their exceptionally high insulation resistance throughout their extremely long life. Unlike conventional tubulars, Sealdtites have no cardboard tubes to grow soggy, or internal voids to collect moisture.

Hi-Temp Sealdtite Capacitors have attractive labels in bold, easy-to-read type. Their smooth surface attracts no dust and drips no wax.

Hi-Temp Sealdtite tubulars are available with either Halowax-impregnated or mineral-oil impregnated sections to fit your application requirements. Eleven mold sizes make for maximum space economy. Complete dimensions for standard ratings are given in Catalog Bulletin SPD-200.

All-purpose Sealdtite Capacitors are available for prompt delivery at no increase in price.

Investigate today!

Solar Manufacturing Corporation, 1445 Hudson Blvd., North Bergen, N. J.

★ Trade Mark

SOLAR CAPACITORS
"Quality Above All"

BUSINESS BRIEFS

By W. W. MacDONALD

Buyers' Guide Issue idea hinted at on p 69, February, has now jelled. We are going to include a special editorial section giving the electrical, mechanical and other characteristics of materials important to designers of electronic equipment and the components used in such gear.

Included will be such things as *insulating materials, plastics, ceramics, glass, metals, magnetic materials, chemicals, gases, radioactive materials, crystals, acoustic materials,* and *finishes.*

The special issue will reach readers around the middle of June, between the times they receive the regular June and July numbers.

Take A Piece Of Paper, sandwich it between a thin sheet of Lucite and a similar sheet of celluloid. Place sandwich on insulated surface and rub hard with dry cloth. Flip sandwich over.

Remove top sheet. Dip small, pointed artist's brush in nonconducting dye. Hold tip of brush an inch above paper and write in the air. You will find that static electricity attracts the dye to the paper in a fine spray and that what you have written in the air appears on the paper, much as if it had been written with a pen.

Here's a principle that appears to have many important applications, particularly in the publishing and textile industries. We're on top of it, watching completion of a demonstration machine and awaiting erection of a pilot plant. When these are ready there'll be technical details in our feature pages, probably sometime this summer.

Tea Would Taste Better in restaurants if the water used to make it was brought to precisely the right temperature during preparation. But it is hard to maintain water at this temperature with existing equipment.

The Tea Association thinks the problem might be solved by designing 10 or 15-cup commercial units employing electronic heating to bring water up to the proper temperature in a matter of seconds. We ourselves suspect that electrical rather than electronic heating might provide the answer, but if any of you out there feel differently and want to take a fling at the job, write committee chairman George N. Wicc at the National Urn Bag Company, 3408 Northern Boulevard, Long Island City 1, N. Y.

FCC Licenses, at the end of 1947, were as follows:

Broadcast Stations	
A-M	1,962
F-M	1,016
Remote Pickup	590
TV (exp.)	91
TV	73
Educational	40
International	37
Other	31
	3,834
Non-Broadcast Stations	
Amateur	75,000
Aeronautical	20,818
Marine	14,254
Public Safety	4,653
Land Transportation	2,447
Industrial	2,028
Miscellaneous	1,307
	120,507

Licensed radio operators were listed as follows:

Commercial	341,000
Amateur	81,000
Special Aircraft	61,999
	483,999

Personal And Business interests clash when we spend a quiet evening at home listening to f-m. On the one hand, the chief attraction of the service for us is freedom from announcements. On the other, we keep wondering how long this lovely music can play on, like Muzak, without advertising support.

We hope the programs stay as they are. And we hope the stations begin to make money. A spot for a Jekyll and Hyde, if we ever saw one.

If There Is Any Doubt in your mind about the speed with which f-m receivers are being sold watch the rooftops in towns that have stations when passing through by car, bus, or train.

The number of dipole-reflector rigs we spotted on a run to St.

there IS a difference.

PYROVAC the new Eimac plate material makes a better vacuum tube anode . . . on all counts.

1. **LIFE . . .** Tubes with tantalum plates formerly giving 3000 hours of service, now, with Pyrovac plates operate in excess of 15,000 hours . . . a 400 percent increase.

2. **OVERLOADS . . .** With Pyrovac plate, 65 watt tubes have dissipated 900 watts—a 1280 percent momentary overload—without indication that the eventual life of the tubes or their characteristics were affected. In normal service these tubes are still going strong. Excessive plate dissipation due to tuning procedure and circuit failure normally won't mean the loss of your tube.

3. **MECHANICAL CHARACTERISTICS . . .** Pyrovac is easily welded, enabling rugged shock-resistant mounting. It is a "black body" radiator and possesses excellent characteristics as an electrical conductor.

4. **COSTS . . .** Pyrovac plates in Eimac tubes cost you no more, yet since they enable longer life you actually get more for your vacuum-tube-dollar.

5. **PROVEN IN SERVICE . . .** Pyrovac is the result of millions of hours of life tests. The universal acceptance of the 4-125A and the 4-250A in all fields of electronic endeavor can, in part, be attributed to Pyrovac for contributing overload resistance, life, and a general ability to "take it."

THESE ARE THE TUBES WITH PYROVAC PLATES

EIMAC TUBE TYPES	PLATE DISSIPATION watts
TETRODES	
4-65A	65
4-125A	125
4-250A	250
4-400A	400
4-1000A	1000
TRIODES	
25T	25
3C24	25
35T	50
35TG	50
75TH	75
75TL	75
100TH	100
100TL	100
152TH	150
152TL	150
250TH	250
250TL	250
304TH	300
304TL	300
450TH	450
450TL	450
750TL	750
1000T	1000
1500T	1500
2000T	2000

EITEL-McCULLOUGH, Inc.
193 San Mateo Ave., San Bruno, California

Export Agents: Frazar & Hansen 301 Clay St., San Francisco, Calif.

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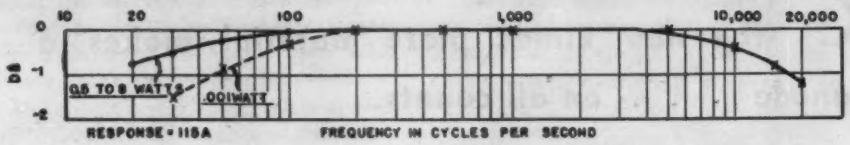
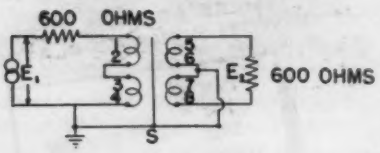
1st LINE PERFORMANCE *Proved in* ADC 2nd Line Transformer

An **ADC** 115A (Industrial Series) impedance matching transformer, picked at random from stock, was submitted to tests to compare its performance with that of other makes of *1st line* transformers. Here are the results. Compare performance of the **ADC** transformer with that of other makes.

FREQUENCY RESPONSE

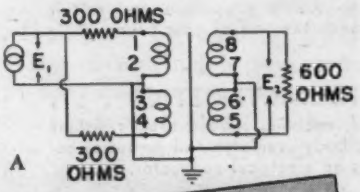




It may be noted that altho the permeability of magnetic materials drops at low flux densities, the **ADC** transformer has sufficient reserve inductance to allow for this even at low power levels. At 40 db below maximum power level it exceeds the response guarantee. Insertion loss at 1,000 cps was 0.75 db.

LONGITUDINAL BALANCE

The most common interference voltages encountered in telephone line transmission are longitudinal; that is, the induced voltages in both wires are in phase with respect to ground. These can be removed from the signal voltage only by means of a well balanced line transformer. Illustration "A" shows the test circuit used to measure the degree of removal of these interference voltages. Level reduction on the **ADC** 115A transformer was 67 db at 100 cps and 56 db at 10,000 cps.



A

CONSULT ADC for your engineered transformer where exacting specifications require positive results. ADC's policy assures you the finest available materials and workmanship to give you the very best electronic components.

ADC QUALITY PLUS TRANSFORMERS
Finest transformer made. For AM and FM broadcast stations and recording studios. ± ½ db 30-15,000 cps.

MANUFACTURERS, JOBBERS: Write today for catalog of **ADC** electronic components or for information on units engineered to your requirements.

AUDIO DEVELOPMENT

Audio Development Co.

2835 13th AVE. S., MINNEAPOLIS 7, MINN.

"Audio Develops the Finest"

Louis a short time ago was reminiscent of the early a-m days, when enthusiasts put up skywires resembling everything from umbrellas to pawnshop balls.

Receiver Production by RMA members in 1947 is estimated at 17,695,677 units. Breakdown by months:

January	1,564,171
February	1,379,966
March	1,377,269
April	1,759,723
May	1,316,373
June	1,213,142
July	1,155,456
August	1,265,835
September	1,339,980
October	2,002,303
November	1,615,541
December	1,705,918

Included in the figures are 8,029,637 auto radios, and 178,571 television sets. Some 72 percent of all home radio receivers made were table models, 13 percent consoles, and 15 percent portables.

In addition to the radio and television receivers tabulated above, members made 291,410 phonographs and 224,945 record players.

Projection Television is about to get another shot in the arm, the needle being wielded this time by designers up at the North American Philips lab.

Nearly ready for sale to tele set manufacturers, in more or less packaged form, is an extremely compact unit comprising a stubby c-r tube having a high-intensity screen just a little larger than two inches in diameter, an optical system, and a mirror that shoots the picture up to any conventional translucent screen. A high-voltage power supply using fewer than the usual number of tubes is also involved.

A detailed technical description of the system is in preparation and will soon appear in ELECTRONICS.

Associate Editor Zeluff has an idea worthwhile passing along. He thinks lots of people who have television sets with small screens will soon want larger pictures, largely so that more can watch. So, how about auxiliary cathode-ray tube units that can be attached to such sets and used simultaneously some place else in the same

room? And, if and when they become available at reasonable cost, auxiliary units with larger screens?

Hotel installations using the central receiver and remote cathode-ray tube system are already being made. Why not apply the idea to homes?

Transmitter Equipment Sales by RMA members exceeded $97,000,000 during the first half of 1947.

Makers of broadcast transmitting and studio equipment shipped $9,253,358 worth. A-m transmitter sales totalled $2,319,006, f-m transmitter sales $1,820,633. A-m and f-m studio equipment sales went to $2,205,382. Antenna equipment for both types of broadcast service brought in $433,767. Television station equipment of all kinds totalled $1,354,633.

General communications equipment sales totalled $2,589,468 for vhf equipment and $746,902 for medium frequency. Aviation radio gear went for $4,061,072. Marine transmitting equipment sales were $1,677,703. Sales of piezoelectric quartz crystals hit $456,137, of which $315,169 worth went to equipment manufacturers.

The U. S. Government received delivery of $78,347,341 worth of gear in the first half of 1947.

Test Equipment can be made smaller and lighter by using miniature tubes, batteries and component parts. Some instruments hitherto limited by size and weight to laboratory use could be made sufficiently compact for field applications, thus broadening their market.

An Indian Radio Company has ordered 100,000 two-tube sets produced by the Sargrove method. In case you've forgotten, that's the method employed to turn out the machine-made radio appearing on the cover of ELECTRONICS for February.

One Way To Find Time: Studying in his cell from books furnished by his mother, a Cranston, R. I. man is said to have become an electronic expert while serving a 35-year sentence for the second degree murder of his fiance.

New! INDISPENSABLE ALL INCLUSIVE! COMPLETE!

GEIGER-MÜLLER LABORATORY COUNTING RATE METER

MODEL - RM4

A COMBINED COUNTING RATE METER AND COUNTER SET

Direct reading counting rate meter with FOUR full scale ranges of 5, 50, 500 and 5000 pulses per second. Provision for connection of external 5 m. a. recording milliameter. Recorder circuit for operation of impulse register (recording clock). Regulated high voltage power supply for counter tube. Built-in loudspeaker for aural monitoring. Pulse equalizing and sharpening stages. Operates with self-quenching OR non-self-quenching counter tubes. Provision for connecting scaling circuit, impulse register, oscilloscope, recording milliameter and calibrating input signal. Price only $350 less counter tubes and recording clock. For complete description send for Bulletin No. 471.

HIGH SPEED GEIGER-MÜLLER LABORATORY SET

MODEL LS64

CHECK THESE OUTSTANDING FEATURES:

All of the newest circuits—simplified and modernized—reliable and foolproof. Uses the famous Higinbotham Scaling Circuit—SCALE OF 64 (Used under license agreement with U. S. Atomic Energy Commission). Build-in recorder clock of zero reset type—counts up to 9999 before recycling. Regulated high voltage power supply for counter tube, with front panel voltmeter. Suitable for use with self-quenching or non-self-quenching counter tube. Bank of neon indicator lamps for interpolation of count and indication of proper scaler operation. Small, compact, light in weight—constructed completely on one 13"x17" chassis with 8-¾" rack type front panel. PRICE ONLY $360.00 complete with tubes and built-in recording clock. Send for Descriptive Bulletin No. 472.

El-Tronics INC.

1920 LINCOLN-LIBERTY BLDG.
PHILADELPHIA 7, PENNA.

MANUFACTURERS OF SPECIALIZED ELECTRONIC APPARATUS

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MALLORY ORIGINATED ELKONITE* METALS—

ELKONITE

and only Mallory has the years of experience with their complex fabrication

ELKONITE is the registered trade mark for a series of metals originated by Mallory which derive their effectiveness from the skillful compounding that Mallory has developed through many, many years of pioneering in the field of powder metallurgy.

Elkonite metal proved so dependable under the most severe conditions that it quickly became standard on most heavy duty circuit interrupting equipment. It also proved indispensable in the field of resistance welding and in countless applications requiring its particular characteristics.

The success of Elkonite metal is so well established that the trade mark has been mistakenly applied to materials that are sold with the implication that they will match the performance of true Elkonite metal.

Mallory has made true Elkonite metals for years. Only Mallory can guarantee the correct formulation that gives hardness, high electrical conductivity, resistance to mechanical wear and to sticking and erosion by arcing—the qualities that have made the word Elkonite a symbol of dependability.

ONLY MALLORY MAKES AND SELLS GENUINE ELKONITE METAL

**Reg. U. S. Pat. Off.*

P. R. MALLORY & CO. Inc.

MALLORY ELECTRICAL CONTACTS & CONTACT ASSEMBLIES

P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA

CROSS TALK

▶**ALEX . . .** Out near the end of Long Island stand several monuments to one of the grand figures of electronics. Here are antennas the like of which the younger generation of experts has never seen. They are a mile long and 400 feet high. They operate in the region of 15 kc and they get their power, several hundred kilowatts of it, from huge generators rotating at high speed.

The genial figure who has thus created his own monument is E.F.W. Alexanderson, just retired after 45 years with General Electric. "Alex" not only produced the alternators which bear his name but had much to do with the multiple-tuned antennas which launch the energy into the ether. His contributions to electronics, however, are not confined to dot-and-dash techniques. The industry still remembers with awe television demonstrations in Schenectady where his giant scanners made possible theater-size images. Industrial electronics, too, has felt his handiwork. And above all, Alex has the human touch, so often missing in those who deal primarily with machines—and big machines at that.

▶**STANDARDS . . .** Recent changes in two basic physical standards remind us that arbitrarily defined units of measurement are subject to alteration. From W. F. Meggers of the National Bureau of Standards comes news that a new and better standard of length is available. It is a spectrum line, of green color, produced by mercury 198. This isotope of mercury does not occur in nature, but is produced by neutron bombardment of gold. The wavelength of this line is, according to Dr. Meggers, superior to the long-established standard red line in the spectrum of cadmium, and far easier to reproduce than the standard meter bar now preserved in Paris. So nuclear technology provides a new standard, measurable to an accuracy of one part in 100,000,000.

The other change is less exciting, but perhaps of equal practical importance. Effective this year, the standard ohm becomes about 1/20th of a percent smaller than formerly. The formerly used international ohm was 1.000495 absolute ohm. The absolute ohm is the newly defined standard. The practical effect is that precision resistors, whose tolerance is 0.1 percent or better, must be made to the new standard. For all other practical purposes, we are glad to report, we may cleave to the obsolete (non-absolute) ohm.

▶**OVERSUPPLY . . .** While busily engaged in trying to control the inflationary aspect of our feast-and-famine economy, we may lose sight of a similar oscillation in the supply of electrical engineers. Through a now-recognized defect in the draft policy of the last war, we virtually stopped production of young engineers for nearly five years. Meanwhile we vastly enhanced the attraction of the electrical industry, particularly the electronics part of it, by introducing radar and similar wonders to vast numbers of soldiers and sailors. So students, largely G.I.'s, have since flocked to the electrical departments of colleges throughout the land. The committee on manpower of the American Society for Engineering Education has surveyed this rush and sounds a warning. By 1949, there will be an oversupply of electrical engineers, by 1950 an "exceedingly high" oversupply, or so the A.S.E.E. experts claim. Perhaps so. But in 1948 we still have a shortage of young men, as well as experienced men. If the products of electrical science continue to command an increasingly large portion of the national income, as they have since prewar years, our industry will absorb all the good men offered.

▶**MICROSCOPE . . .** The electron microscope has climbed in magnifying power to 300,000 diameters and, like telescopes of new power, is revealing hitherto unknown worlds. The latest adventure has been reported at Philadelphia by Dr. James Hillier, speaking before the Electron Microscope Society of America. Microscope pictures taken at the RCA Princeton Laboratories show viruses attacking bacteria and destroying them. Both virus and bacteria were killed by the passage of the electron beam in the microscope, but they preserved their relative positions at the instant of exposure and so showed, in successive pictures, the advance of the attack. This direct insight is of the greatest importance in studying the nature of virus diseases. A new double electron lens did the trick, revealing bodies only one four-hundred-millionth of an inch in diameter.

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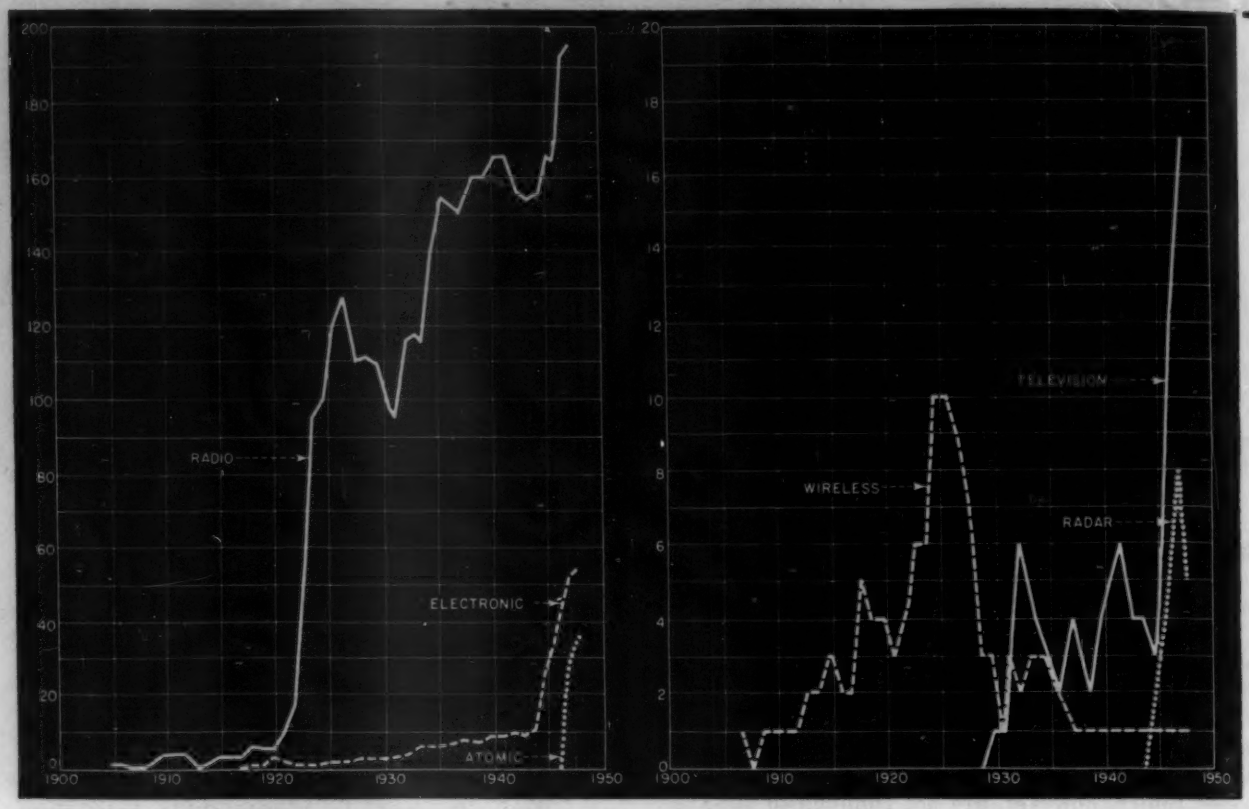
NEW WORDS



When a new technical word having popular appeal is publicized into the language, businessmen frequently ride on its coat tail and incorporate the word into the names of their firms. Sometimes these firms are engaged in the field so intimated, sometimes not

THE NAMES of new advances in science are often employed in connection with business ventures. Their use as part of company names tells an interesting story.

The trend is easily traced by an examination of telephone directories of past years. Such a search of New York (Manhattan) telephone directories since 1904 reveals the growth and sometimes the decline of several words in our field. It also discloses the extent of their popular appeal over the years.

The words chosen for this study were *Radio, Wireless, Electronic* (including *Electron* and *Electronics*), *Television, Radar* and *Atomic.* The 1904 starting date was chosen as directories back to that date were conveniently available. This date also pretty well antecedes the common use of most of the words.

The number of listings in the telephone directory is plotted in the accompanying chart. (Note that the fluctuations do not follow at all closely the boom of the late twenties or the depression of the thirties.)

Radio

Strangely enough, the word *radio* appears two years before the word *wireless.*

In 1904 and 1905 there was a single entry, the Radio Chemical Company. The next two years showed no use but in 1908 it reappeared, one listing being a radio telephone company. In 1910 a radio wireless station was listed. In 1912 the word disappeared, but it returned the following year. By 1917 there was a total of six in use, but none of them were really applicable to the science of radio as we know this very popular word today.

The Radio Corporation of America showed up in 1920, and in 1931 the completion of Radio City swelled the list considerably. The period of most rapid growth was between 1919 and 1924, when the number of mentions increased from five to 100. Use of the word is now pushing the 200 mark.

The publicity value of the word *radio* caused it to be used in connection with many enterprises such as awnings, grills, picture frames, meat shops, slippers, neckwear, and wet wash.

The term *radionic* has not so far made a great deal of progress.

Wireless

The word *wireless* first made real news in this country as a result of the reception of Marconi trans-

COME . . . . and GO

By W. C. WHITE
Research Laboratory
General Electric Co.
Schenectady, N. Y

atlantic signals on December 12, 1901. However, it did not appear in the New York telephone directory until 1906. It was not represented in 1907, which year incidentally was the only one covered by this survey that yielded no entry of any of the words chosen.

It is rather prophetic of the early era of wireless that the first entry in 1906 was for the Wireless Securities Exchange, which proved to be short-lived, at least under that title.

The word *wireless* was back again in 1908 with the well-remembered and relatively long-lived Wireless Specialty Apparatus Company.

Another big boost in the news value of the word occurred in connection with the wreck of the S.S. Republic, in 1909, and to an even greater extent as a result of the Titanic disaster in 1912. However, its use in connection with business enterprises did not seem to be immediately affected. The number of appearances in the telephone directory reached a maximum in 1924 and 1925 with 10 entries.

As in the case of the word *radio*, many of the listings were not really connected with the science.

By 1937 the listings were down to one entry, and this one and only entry has remained up to the present. It is for a printing company. Incidentally, in 1926 there was a Wireless Radio Corporation in Brooklyn.

Electronic

Although none of the words stemming from *electron* appeared until 1917, the word *elektron* was listed in 1904 and 1905, applied to an elevator company. The word *electron* appeared first in 1917 in connection with a chemical company. The number of entries varied slightly but never reached over four until after 1932.

The word *electronic* first showed up in 1926 and *electronics* in 1930 in connection with this publication. The magazine remained the sole representative of this form of the word in the telephone directories until 1944.

For some reason not entirely evident, the three words based on *electron* have been applied appropriately to a much greater extent than *radio* or *wireless*. A rapid increase occurred between 1943, with 11 entries, and the latter part of 1946, with 52 entries. Use apparently is still on the increase.

Television

The word first was used in the telephone directory in 1929, in connection with a television-radio shop. There was an increase from a single entry in 1930 to six entries in 1931. Then it varied back and forth between these limits until 1944, when it started a rapid and continuous increase, reaching 17 in the latest issue.

As in the case of *electronic*, listings under television are largely connected with the actual industry.

Radar

The word *radar* made its first appearance in 1944 with two entries, one a paint and one a novelty company. It appears to have reached a maximum of eight mentions in 1946, none of them having any apparent connection with the science. Typical firms listed dealt in blouses, novelties, restaurant supplies, paints, and slippers.

The use of this word in the telephone directory will probably decrease and may well disappear after a few years.

Atomic

The 1945 fall directory was probably well along in preparation when the atom bomb was dropped over Hiroshima so there were no listings containing the word *atomic* in that issue. But in the next issue, in the spring of 1946, it appeared 19 times. None, of course, were directly applicable to the scientific development.

The great popular appeal of the word is indicated by the fact that it showed more listings in the issue of its first appearance than any of the other words did after a growth of ten years. The listings showed activity in handbags, pleating, rainwear, and surgical supplies. By the 1946 fall issue, the number had grown to 30 and added lines were neckwear, undergarments, podiatry, art studios, food, and jewelry.

By the fall of 1947, the number had grown to 35. One appropriate entry did appear then, the Atomic Energy Commission.

Nucleonic

To date the word *nucleonic* has not appeared. It offers a wonderful opportunity if you are going into neckwear, novelties, etc.

You may have the field to yourself for at least one issue of the Manhattan directory if you start now.*

* ED. NOTE. You will *not*. See "*Nucleonics*," a McGraw-Hill Publication.

REPEAT PERFORMANCE

THE EDITORS almost let this article slip through their fingers. So unusual was the theme, and so light the treatment, that it seemed not to fit a serious technical publication.

BUT a good story will not die. The editors re-read it, and again enjoyed it. Why keep it from readers? Editors can get too serious. So here it is.

BILL WHITE, by the way, is not only a charter subscriber to ELECTRONICS but is a charter contributor as well. An article appeared under his signature in our first issue, back in April 1930

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Electronic Preservation of Food

Experiments indicate that foods of many varieties can be preserved over long periods, without alteration in appearance or taste, by exposing them in their sealed containers to ultra-short-time pulsed cathode rays from a capacitron. Sterilization of drugs without decrease in potency is also possible

By WOLFGANG HUBER*
Research Laboratories
Electronized Chemicals Corp.
New York, N. Y.

THE IMPORTANCE of electrons moving within evacuated tubes has been amply demonstrated. By contrast, comparatively little has been done with electrons released from the confinement of tubes, particularly in the field of food preservation.

In 1894 Lenard[1] brought cathode rays out through a window in the wall of a tube. But the cathode-ray tube remained a low-voltage, low-current device until 1926 when Cooldige[2] developed a tube capable of operation at several ma and up to 350 kv. With this type, electron beams of sufficient intensity to permit practical experimentation with chemical and biological objects were obtained.

Still higher electron velocities were obtained by the subsequent development of cascaded cathode-ray tubes. Many investigators[3] used this method to expose a wide variety of materials of inorganic as well as organic origin to the action of electrons. The results of the biological experiments were not very encouraging, however. Micro-organisms within the penetration range were killed, but irradiated products showed pronounced changes in taste, odor and appearance.

HEATLESS

Energy developed by the capacitron is cold energy. Thus limitation of micro-organism and enzyme activity may be accomplished while food is in any physical state . . . frozen, raw, partly or fully cooked

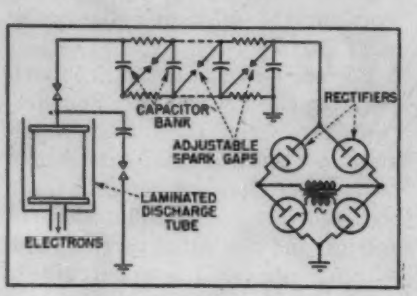


FIG. 1—Basic circuit of the electronic impulse generator

Capacitron Development

Biological and medical experiments undertaken by Brasch and Lange[4] in cooperation with Beck and Haelberstaedter opened new possibilities. These men used a capacitron, an apparatus which produces high voltages and great electron intensities during ultra-short-time periods. It was indicated that the release of high intensities during ultra-short-time periods killed micro-organisms in much the same way as continuous current-voltage generators but without radically changing taste, odor or appearance.

Initial experiments were carried out by the utilization of voltage produced by lightning.[5] This source of voltage was obviously unreliable and further progress was intimately connected with the development of an impulse generator developed by E. Marx[6] and shown in Fig. 1. A number of capacitors are charged in parallel, through resistors, from a rectifier unit. Discharge of the capacitors in series is accomplished by means of gaps which spark over at predetermined voltages.

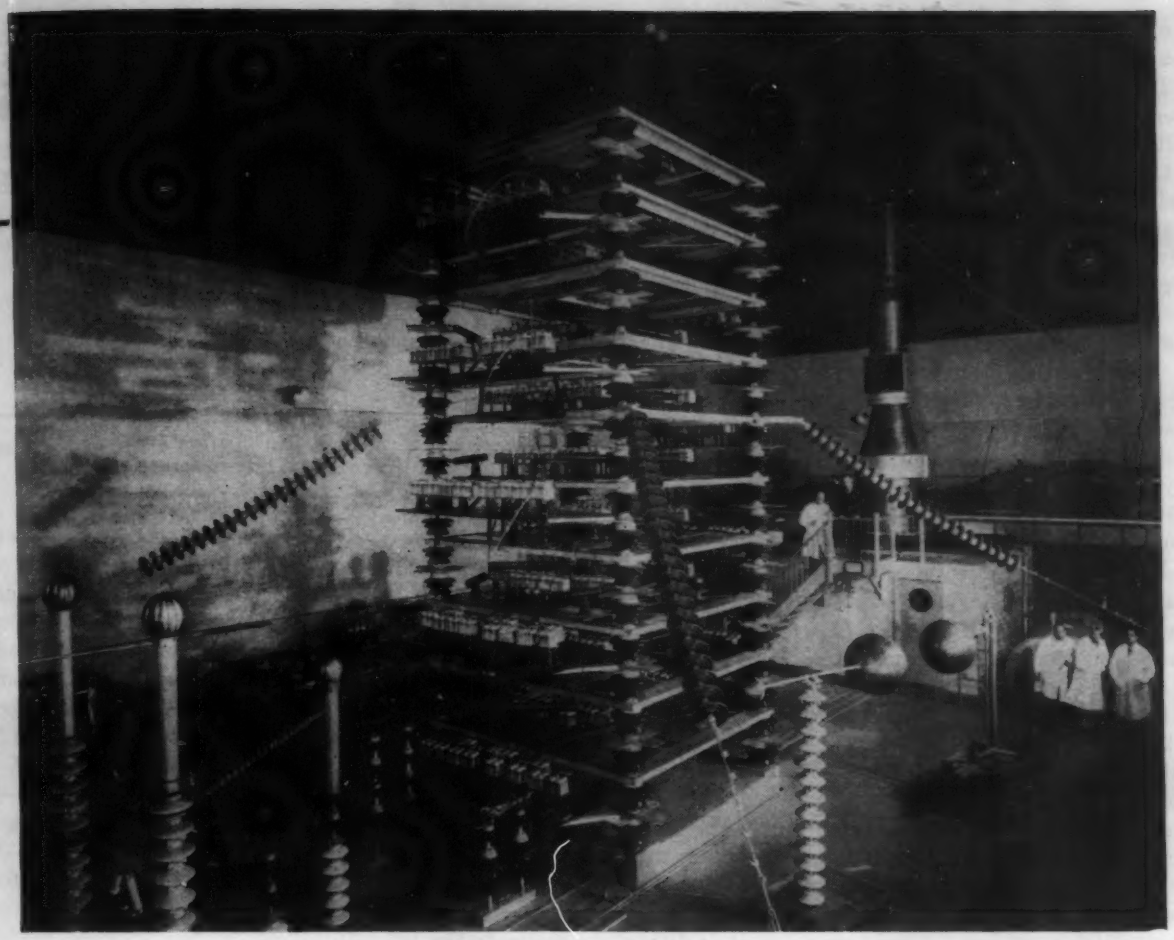
The availability of impulses of several million volts from a generator now made it imperative to develop discharge tubes that would handle these voltages continuously and without breakdown. Brasch and Lange[7] determined that the breakdown voltage depended not only on the status of the vacuum and the construction of the electrodes but also upon the type and structure of the wall of the discharge tube. Breakdown troubles were reduced by lamination of the tube wall and by increase in the lengths of surfaces which were prone to cause gliding discharges. This led in 1930 to the development of the so-called laminated tube illustrated in Fig. 2. It consists of alternate stainless steel or nickel, insulating resin, and rubber discs.

In order to avoid excessive bombardment of the walls with electrons it is important to construct the tube in such a way that the relation of length to width is not materially in excess of 8 to 1. In large capacitrons the ratio may be as low as 2 to 1. To avoid flashovers the tube is immersed in oil.

Practical Design

Experimental work by A. Brasch and the author[8] has so far been carried on with the experimental capacitron pictured in these pages. Line voltage is transformed to 100,000 volts and converted into d-c by a set of rectifier tubes. Induction coils used in lieu of resistances permit a capacitor-bank charging fre-

* From a paper presented before the 1947 National Electronics Conference in Chicago.



Experimental capacitron used in the tests

quency of 50 to 100 times per minute. The generator itself consists of capacitors arranged in 30 banks of 100,000 volts each, thus giving a peak output voltage of 3,000,000.

The intensity of each individual impulse is of the order of thousands of amperes and the release time of the order of 10^{-6} second. The electrons reach the open through a window device which consists of a grill supporting a thin metal foil. Foils of beryllium alloys, which have the best strength and ductility characteristics, are not yet available. Therefore, we are at present using 0.05-mm foil of a hard aluminum alloy. The efficiency of the device, as compared with other corpuscular accelerators, is relatively high. According to calorimetric determinations, about 35 percent of the surge generator intensity is converted into electrons.

The simplicity of capacitron design permits the attainment of practically unlimited voltages and intensities, particularly if the entire surge generator together with the discharge tube is immersed in a liquid insulating material contained in a grounded tank. The general design of such a unit, which will be a prototype for commercial uses, is shown in Fig. 3. In this unit, the capacitor banks and the discharge tube are immersed in oil in a submerged concrete pool, with only the pumping equipment, the exit window and the conveyor belt above ground in a separate concrete housing. The spark gaps are hermetically sealed in compressed gas and the beam of electrons is bent around by a system of magnets to facilitate

Table I—Penetration Range of Electrons in Water

Velocity*	Accel. Pot. (kv)	Max. Range (mm)	High Intensity Range†	Depth of Max. Intensity (mm)
0.55	100	0.03	.....	.....
0.70	204	0.83	.....	.....
0.78	300	1.40	.....	.....
0.80	340	1.60	.....	.....
0.90	662	2.46	.....	.....
0.94	1,000	5.20	.....	.....
0.97	1,600	7.70	0– 2.7	1.3
0.985	2,400	12.50	0– 4.5	3.0
0.993	4,000	21.00	0– 7.5	6–7
0.998	8,000	42.00	0–14.0	10–12
0.999	12,000	62.00	0–22.0	16–18

*Expressed as fraction of velocity of light
†Higher than at surface

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the use of conventional conveyor equipment and to eliminate x-rays.

The penetration range of electrons depends on the accelerating voltage and the density of the target. Table I illustrates this, using water as a target, as well as the fact that electrons exercise more intensity at a certain depth than on the surface. The latter effect is due to the phenomenon that with increasing electron speed scattering will be predominantly in the forward direction. This is of considerable practical importance, since it avoids unduly high energy absorption in any container wall.

Penetration in water with 5,000,000 volts is about 25 mm. After electrons pass through the discharge-tube air exerts a bushing effect upon them. In 5 inches distance from the window, for example, an area of at least 380-mm diameter is covered. With a penetration range of 25 mm it is thus possible to process with one impulse 2.83 liters of one particular material. If we assume an average discharge frequency of only 30 impulses per minute this would be equivalent to a capacity of 85 liters per minute and about 5,100 liters, or 5.5 tons, per hour.

Table II indicates the nature of changes in several substances when subjected to continuous radiation and, by comparison, to ultra-short-time radiation. Using ultra-short-time impulses with intensities far above maximum continuous radiation values recommended in the literature, we note no formation of vitamin D in ergosterol. Our interpretation of this fact is that the first step in the photoactivation of ergosterol, namely, the isomerization of the angular methyl group on C-10, has a reaction time considerably in excess of 10^{-6} second.

Preservation of Foods

Table III illustrates the effectiveness with which foods are preserved by means of capacitron radiation. For example, slices of raw beef, veal and pork were put into thin-walled glass containers which were sealed off under air and exposed for four impulses. The energies applied were far in excess of the minimum sterilization dose.

Tests for sterility were made directly after irradiation and at the end of the storage period, which was in some few instances coincident with perceptible change in appearance but in most cases arbitrary. Experiments are continuing, so it is difficult to estimate the extent of ultimate storage stability for many samples. In the protein series, for example, we feel that we are nowhere near the limit.

Table II—Comparison of Continuous and Ultra-Short-Time Radiation

Substance	Continuous Radiation	Effect	Capacitron Impulses of 10^{-6} Sec
Ergosterol	u-v, α, β	vitamin-D formation	no change
Casein, Egg Albumen	β, γ	decomposition, oxidation	no change
Butane, Heptane	α, β	H_2, CH_4 evolution, polymerization	no change
Styrene	u-v, α, β	polymerization	no change
Castor, Linseed, Tung Oil	u-v, β	polymerization, change of ref. index., iodine no. and color	development of slight flowery odor
Acetone	β	condensation, gas formation	no change
Hemoglobin	u-v, α	inhomogenization, low molecular breakdown products	small % of methemoglobin
Rubber Plant	β	discoloration, drying, latex formation	no change

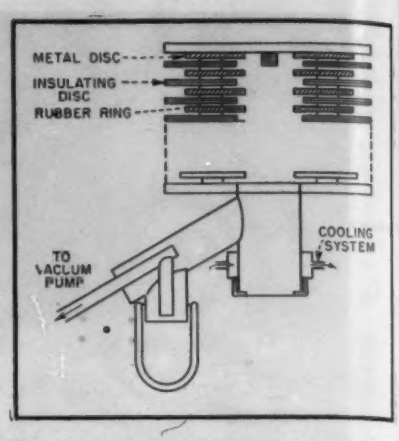

FIG. 2—Laminated discharge tube used in the system

Boiled ham showed decomposition after 63 days, whereas raw fat pork exhibited no change after 207 days. This had us puzzled until we found that the discrepancy was due to differences in packing. The boiled ham samples were packed in double bags of 0.004-inch polyethylene foil, considered ideal because of its low density, and heat-sealed. Decomposition of the sample started around the areas closest to the sealed edges, indicating need for a foolproof, fully airtight plastic container.

Ultra-short-time impulses do not always eliminate all side effects. In the case of butter as well as other products containing butter fat a definite taste change occurs which cannot be classified as any of the previously known taste changes. We call this change irradiated taste. It can be considerably reduced by critical variation of the irradiation conditions, and also by prolonged storage. In the case of cream cheese, irradiated taste completely disappeared after 66 days of storage at room temperature in the original tin-foil wrapper.

Considering the most common use of castor oil, it was rather amusing to find that under radiation this household standby developed a fragrant odor much like that of daisies.

Table III also illustrates the behavior of capacitronized vegetables. The days of storage for the products in plastic containers are somewhat deceiving, since these samples were opened regardless of appearance when we discovered the unsuitability of heat-sealed polyethylene bags for our purpose.

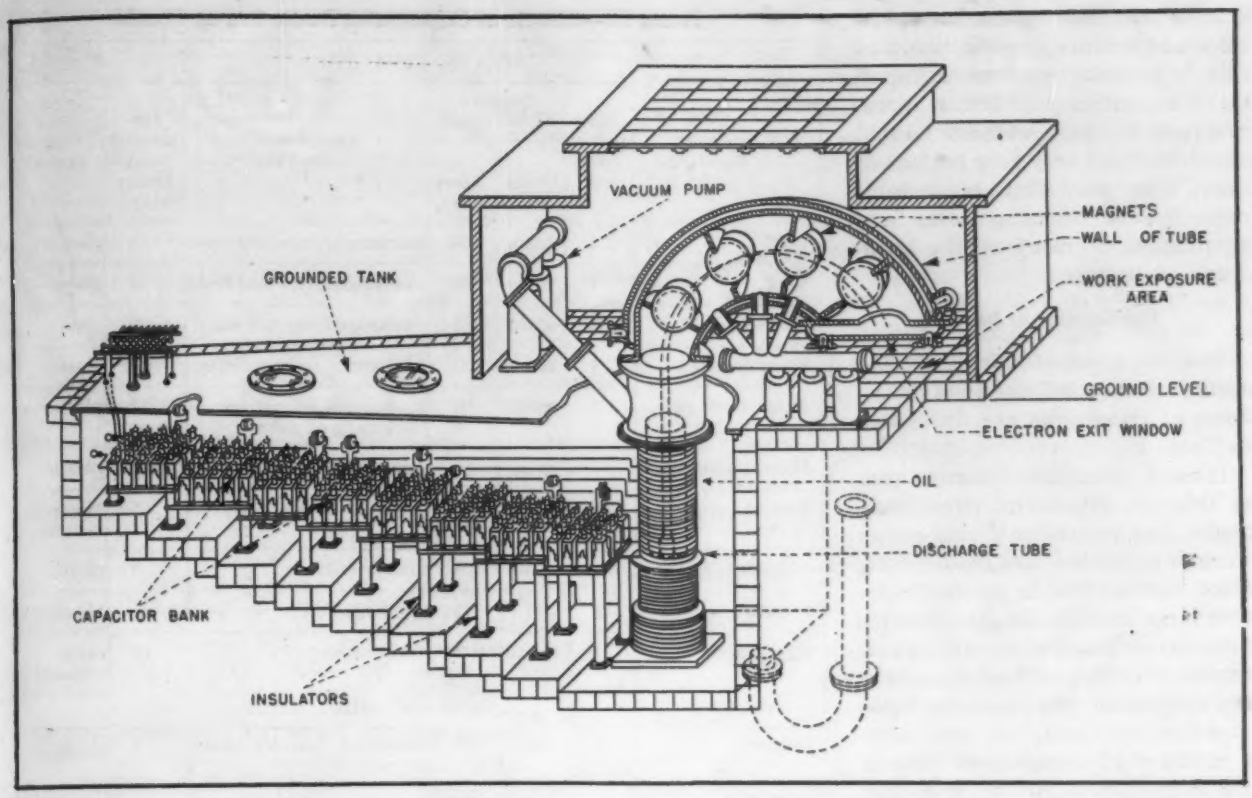

FIG. 3—Prototype of a commercial capacitron

By contrast with the color of substances of animal origin, some plant dyes were found to be much less stable under our conditions of storage. Bleaching is not a radiation effect but develops slowly on storage. It can be reduced by storage away from light. On the other hand, attempts to preserve lettuce have so far been a failure, with the detrimental effects undoubtedly due to irradiation. We do not yet know why.

The color of all except one of the fruits so far tested was well preserved after radiation. The notable exception is strawberries. Indications are that special treatment and storage conditions as well as more rigidly controlled impulse dosages may overcome the undesirable effects.

Surface Sterilization of Foods

All the experiments discussed so far were undertaken for the purpose of studying the maximum extent of preservation obtainable with penetrating electrons of ultra-short-time duration. If, however, only a moderate extension of shelf life is needed then the capacitron can be readily utilized for a process which we have called surface sterilization. In this procedure the irradiation conditions are adjusted in such a way that the electrons penetrate just through the surface of the foodstuff.

We have found that the elimination of micro-organisms from the surface affords a considerable extension of the life of fresh food products, particularly of those that have a rather thick or tough skin, such as apples, peaches, melons, corn, nuts and eggs. That this should be so seems logical if one remembers that except for insect infestations the surface is the main portal of entry for micro-organisms.

We have been able to preserve fruits such as melons, peaches, pears and corn on the cob, wrapped in plastic envelopes, over periods of several weeks at room temperature. Controls kept under identical conditions started to decay after several days.

Another interesting application of the capacitron is the preservation of partly or wholly dehydrated foodstuffs, particularly when the dehydration has been achieved by freeze-drying. And this discussion of preservation of foods would not be complete without mentioning commodities which serve in one way or another as raw materials, intermediates or additives in the preparation of finished food products. These highly diversified products include grains such as wheat, corn and rice, as well as the corresponding flours, beans, nuts, spices, plant extracts, protein fractions and many others. We have achieved preservation of these commodities by elimination of micro-organisms of all types as well as infestations caused by insects, insect eggs or larvae.

Before concluding the discussion of food preservation, I would like to say a few words about capacitron preservation in relation to preservation by refrigeration, particularly by deep freezing. We do not hold the opinion that preservation with penetrating electrons of ultra-short-time duration will be a potential antagonist to deep-freezing techniques. Quite the contrary, we feel that the process can offer great advantages to the processor of frozen foodstuffs. The capacitron offers a means for heatless sterilization and enzyme inhibition. To this, refrig-

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eration can add preservation of color and texture. In addition, and this is probably even more important, capacitronized frozen products can be kept without loss at about 10 F for very long periods of time, thus providing considerable reduction of freezing costs and elimination of many of the headaches of transport.

Sterilization of Drugs

The last topic of this discussion deals with the sterilization of drugs. Some of the results are illustrated in Table IV.

It can be seen that vitamins such as thiamin, riboflavin, pyridoxine, niacin, and pantothenic acid either alone or in mixture are readily sterilized without loss in potency, even with large impulse dosages. Similar data was obtained when testing fat-soluble vitamins, such as vitamin A and vitamin D. The same also holds true for hormones, and even such a mixture of complicated protein molecules as pituitary hormone can be readily sterilized without any loss in potency. Another remarkable result is the radiation stability of antibiotics such as penicillin and streptomycin. They withstand even higher impulse dosage than those given in the table without any loss of antibiotic activity.

To illustrate in this table the sterilization of individual enzyme preparations as well as their sensitivity to penetrating electrons of ultra-short-time duration, I have selected three examples, namely, hyaluronidase, clarase, and trypsin. Two facts are outstanding. First, the margin between sterility dose and activity loss, although rather narrow, is still wide enough to achieve sterilization with little or no potency loss. Second, there are appreciable individual differences in enzyme sensitivity to capacitron radiation.

The sensitivity of individual enzymes as well as isolated enzyme systems to penetrating electrons of ultra-short-time duration is at present under more detailed investigation.

Summary and Acknowledgments

Summarizing the salient features of penetrating electrons from a capacitron as they apply to heatless

Table III—Effects of Capacitron Radiation on Foods

Food	Impulses (10^{-6} Sec)	Storage Conditions* Temp (°C)	Storage Conditions* Time (days)	Appearance, Taste, Odor	Untreated Sample Decay (days)	Container
MEATS, FISH, EGGS						
Beef	4	room	264	unchanged, raw and fried	2	glass
Veal	4	room	238	unchanged, raw and fried	3	glass
Pork, fat	4	room	207	unchanged, no rancidity	2	glass
Flounder, filet	4	room	127	unchanged, no rancidity	1	glass
Roast Beef, red	4	room	94	unchanged except for darkening of color	2	plastic
Ham, boiled	4	room	63	fair, slight decomposition	2	plastic
Bacon, smoked	6	room	156	unchanged, no rancidity	6	aluminum
Chicken a la King	6	+4	74	unchanged	4	plastic
Hamburger	4	+4	83	unchanged	5	plastic
Eggs, pigeon	4	room	194	unchanged	18	cardboard
FATS and OILS						
Butter	5	room	97	preserved, but off taste; no rancidity	3	glass
Margarine	4	room	79	preserved, but off taste; no rancidity	..	glass
Lard	4	room	182	unchanged, no rancidity	8	glass
Olive Oil	6	room	204	unchanged	10	glass
Cream Cheese	2	room	66	unchanged; off-taste after irradiation disappeared in storage	4	tinfoil
Camembert	4	room	82	preserved, ripening process arrested; taste more like cheddar	2	tinfoil
VEGETABLES						
Peas	6	room	184	unchanged, except for slight bleaching	5	glass
Beans, cut	6	room	184	unchanged, except for some bleaching	6	glass
Carrots, diced	6	room	147	considerable bleaching, some loss of texture	5	glass
Potatoes, diced	4	room	64	unchanged, except for some browning	4	plastic
Lima Beans	6	room	227	unchanged	5	glass
Cabbage, diced	4	room	234	unchanged	9	glass
Broccoli, diced	4	room	42	unchanged, except for some bleaching	2	plastic
Spinach, chopped	4	room	83	unchanged, except for some bleaching	3	plastic
Mushrooms	4	room	33	unchanged, except browning of stem and slight loss of texture	1	plastic
Lettuce	3	room	2	soggy, flat tasting and considerable bleaching	1	plastic
Cauliflower, diced	4	room	234	unchanged, slight yellow discoloration	6	glass

*In air and light.

FRUITS						
Food	Impulses (10^{-6} Sec)	Storage Conditions*		Appearance, Taste, Odor	Untreated Sample Decay (days)	Container
		Temp (°C)	Time (days)			
Pineapple, sliced	4	room	94	unchanged	4	plastic
Coconut, sliced	4	room	86	unchanged	3	plastic
Peaches, sliced	4	room	83	well preserved, but slight loss in texture and some browning	1	glass
Apples, sliced	4	room	101	unchanged, except for some browning	2	glass
Blueberries	4	room	65	unchanged, except for slight loss in texture	2	plastic
Raspberries	4	room	69	unchanged, except for slight loss in texture	2	plastic
Strawberries	4	room	41	preserved, but marked loss in texture and color	1	plastic
Cherries, sweet	4	room	64	unchanged	2	plastic
Orange Juice	4	room	128	preserved, but some loss of aroma and sweetness	1	glass
Orange-Grapefruit Juice	4	room	129	unchanged	1	glass
Grapefruit Juice	4	room	134	unchanged	2	glass

*In air and light.

Table IV—Capacitron Sterilization of Drugs

Drug	Impulses (10^{-6} Sec)	Contamination	Potency		Container
			Untreated	Treated	
Thiamine HCl	2–4	unknown	4.6 mg/cc	4.4 mg/cc	glass
Protein Hydrolysate	2	GNB, GPC	.....	.....	aluminum
Penicillin-Na	3	B. subtilis fungi spores	220,000 U	220,000 U	glass
Streptomycin-H_2SO_4	4	B. subtilis	100,000 U	100,000 U	glass
Testosteron	4	B. subtilis	100%	100%	glass
Prolactane	4	.....	100%	110%	glass
Pituitary Hormone	2	unknown	3800 I. U.	4000 I. U.	plastic
Hyaluronidase	2	unknown	100%	97%	plastic
Clarase	2	unknown	100%	87%	aluminum
Trypcin	2	unknown	100%	100%	aluminum
Yeast	2–4	B. subtilis	.....	.....	plastic
Riboflavin	.....	.....	0.07mg/gm	0.07mg/gm	.....
Pyridoxine	.....	.....	0.04mg/gm	0.04mg/gm	.....
Pantothenic Acid	.....	.....	0.10mg/gm	0.10mg/gm	.....
Niacin	.....	.....	0.35mg/gm	0.35mg/gm	.....

preservation and sterilization:

While the energy is cold energy it is of very considerable intensity. The use of such cold energy makes it possible to treat products at temperatures well below freezing and in any physical state—raw, partly or fully cooked.

The application of high intensities for ultra-short-times accomplishes the selective elimination of micro-organisms and enzyme activity which, under such conditions, in many cases runs ahead of undesirable side reactions.

Highly accelerated electrons penetrate to a considerable depth, depending upon the voltage. Furthermore, they release more energy underneath the surface than on the surface. These characteristics permit the treatment of ready-packed items without breakage of the container and with minimum energy loss within the wall of the container, provided the density and the wall thickness of the container materials are kept within reasonable limits.

High accelerating voltages, necessary for the preservation of bulky materials, will not give rise to nuclear reactions, thus eliminating the danger of artificial radioactivity.

The possibility of large-volume processing, due to the high discharge rate and good efficiency, make commercial application of the capacitron feasible and attractive in many fields.

The author gratefully acknowledges the assistance rendered by the staff of Electronized Chemicals Corporation in carrying out this work. In addition, he is indebted to Alexander Astrack Jr., who conducted many of the food experiments.

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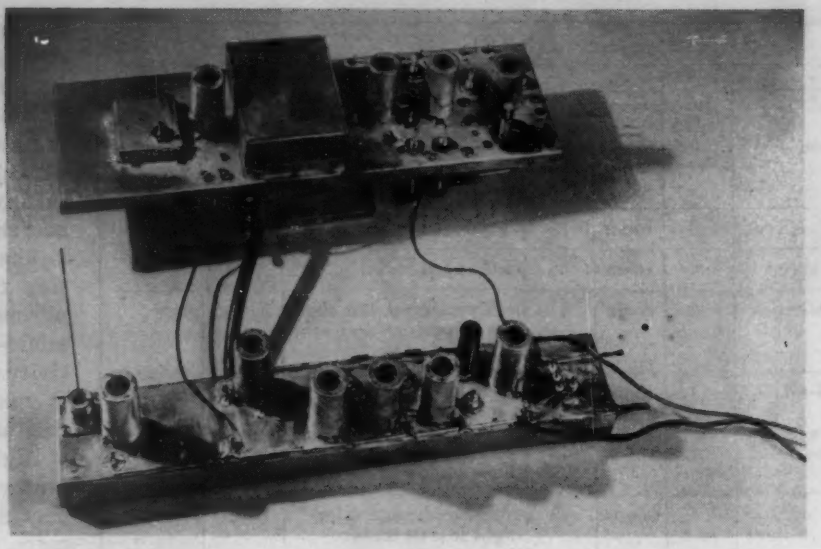
Part II of a Series



Transmitter and receiver for 465 megacycles. The quarter-wave receiving antenna is at the lower left. Local oscillator power for the receiver (bottom) is taken from the transmitter (top)

RECEIVER for the

A RECEIVER operating in the 460–470 mc band is ultimately limited in sensitivity by the thermal noise associated with the antenna resistance and circuit components, and the shot noise due to the tubes. A satisfactory receiver for the Citizens Service should limit on noise and have a good noise figure.

Figure 1 shows the block diagram upon which the present design was based. The preamplifier was used in the interest of improved noise figure, but also improves image rejection and reduces local oscillator radiation. The following assumptions were made:

(1) 10-db gain in the preamplifier.

(2) Unity power gain in the converter.

(3) 250-kc effective bandwidth to receive the 200-kc channel width allowed by FCC specifications. This allows for the ± 0.02 percent tolerance for class-A operation and ± 25-kc deviation of the carrier.

(4) 10-db noise figure.

(5) 10,000-ohm converter plate load.

The available thermal noise power is 4.1×10^{-21} watt per cycle per second.[1] For our bandwidth, the thermal noise power is 1.025×10^{-15} watt. On the assumption of 10-db preamplifier gain, 10-db noise figure, and unity power gain in the converter, the noise voltage across the 10,000-ohm converter plate load is 32 microvolts.

This noise must be amplified to the 1-volt level in three i-f stages. The required gain is 31,200 overall or 31.5 per stage. This gain is readily obtained at 15 megacycles using tubes of the 6AU6 type.

Typical operation for the 6AU6 is as follows: $E_b = E_{c2} = 100$ volts, $E_{c1} = -1$ volt, $I_b = 5.2$ ma, $I_{c2} = 2.0$ ma., $G_m = 3{,}900$ μmho. Using these parameters, the load resistance for a gain of 31.5 is 8,090 ohms.

Four tuned circuits enter the bandwidth considerations. These are the converter plate tuned circuit and the three i-f amplifier tuned circuits. The converter plate tuned circuit will be considerably broadened by the plate resistance of the 6J4 converter and the last i-f tuned circuit by the loading action of the limiters. From these considerations, only the first two i-f amplifier tuned circuits determine the total bandwidth.

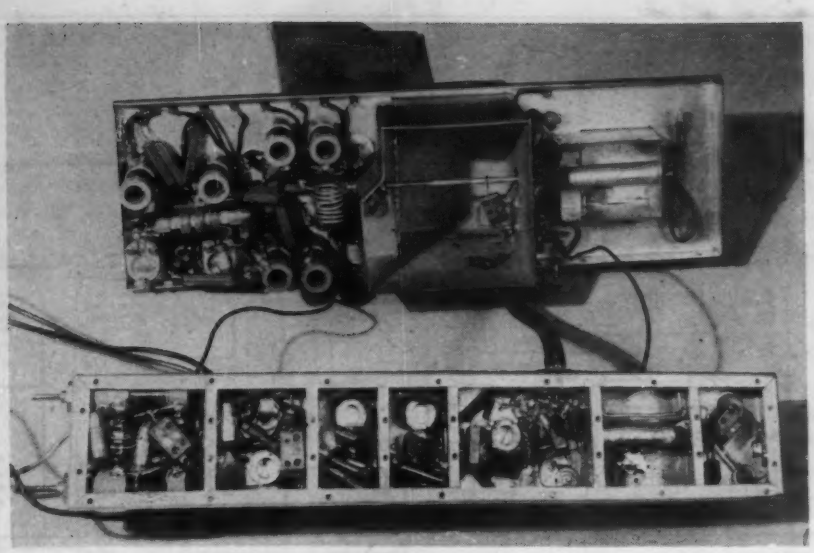
For two single-tuned circuits, the bandwidth factor for 3-db down is 0.64, making the bandwidth per stage 390 kc.[2] This requires a circuit Q of 38 and a capacitance of 50 $\mu\mu$f per stage for the desired bandwidth and gain.

Circuit Details

Limiting is accomplished by two 1N35 germanium diodes biased at 0.5 volt. The limiter clips both positive and negative peaks exceeding 0.5 volt. This circuit is about equivalent to two stages of conventional limiting.

The limited signal then is fed into another 6AU6 i-f amplifier which drives a Foster-Seeley discriminator employing 1N35's as detectors. An inverse frequency network is included for reception of a phase-modulated carrier.

Figure 1 shows the complete



Underview of transmitter and receiver, showing coupling to transmitter doubler cavity resonator for receiver local-oscillator power. The two coil forms at left of the receiver (bottom) form the discriminator transformer

By

WALTER C. HOLLIS

Radio Engineer
*Sperry Gyroscope Co.**

Citizens Radio Service

Circuit operation and construction details for a 465-megacycle superheterodyne receiver for operation in conjunction with the transmitter described in November 1947 ELECTRONICS. Grounded-grid input, cavity resonators, and crystals in limiter and discriminator aid in design of a small-size unit for portable operation

block diagram of the receiver and Fig. 2 is the schematic diagram, without the audio system. The received signal is fed in the receiver from the antenna coaxial transmission line to the input jack, J_1. The input is tuned by L_1 a short length of transmission line, and the tube input capacitance. No tuning adjustment is required as the Q of the input circuit is extremely low due to the low driving impedance of the 6J4 grounded-grid amplifier V_1.

Impedance matching is accomplished by tapping down the line,

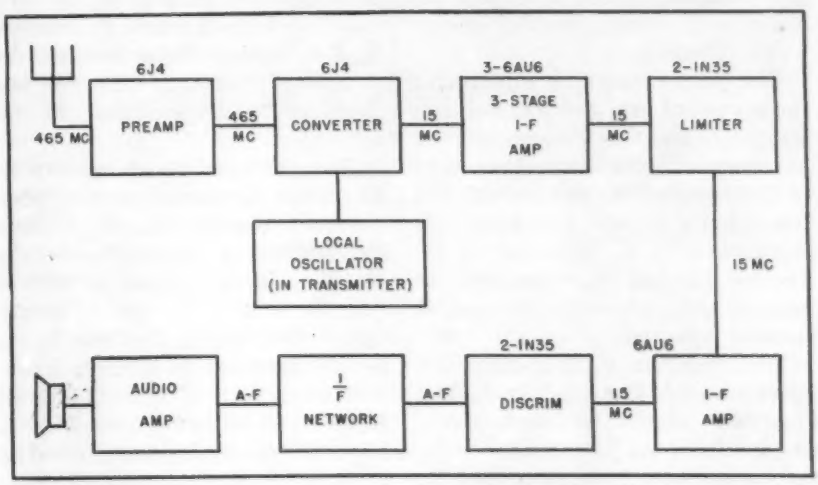


FIG. 1—Block diagram of the receiver. Power supply and a-f circuits are separate from the chassis illustrated in the accompanying photographs

* The equipment described was produced by Mr. Hollis as an independent consultant to the McGraw-Hill Publishing Company. For a full account of ELECTRONICS Citizens Radio Project, see p 80 of the November 1947 issue.

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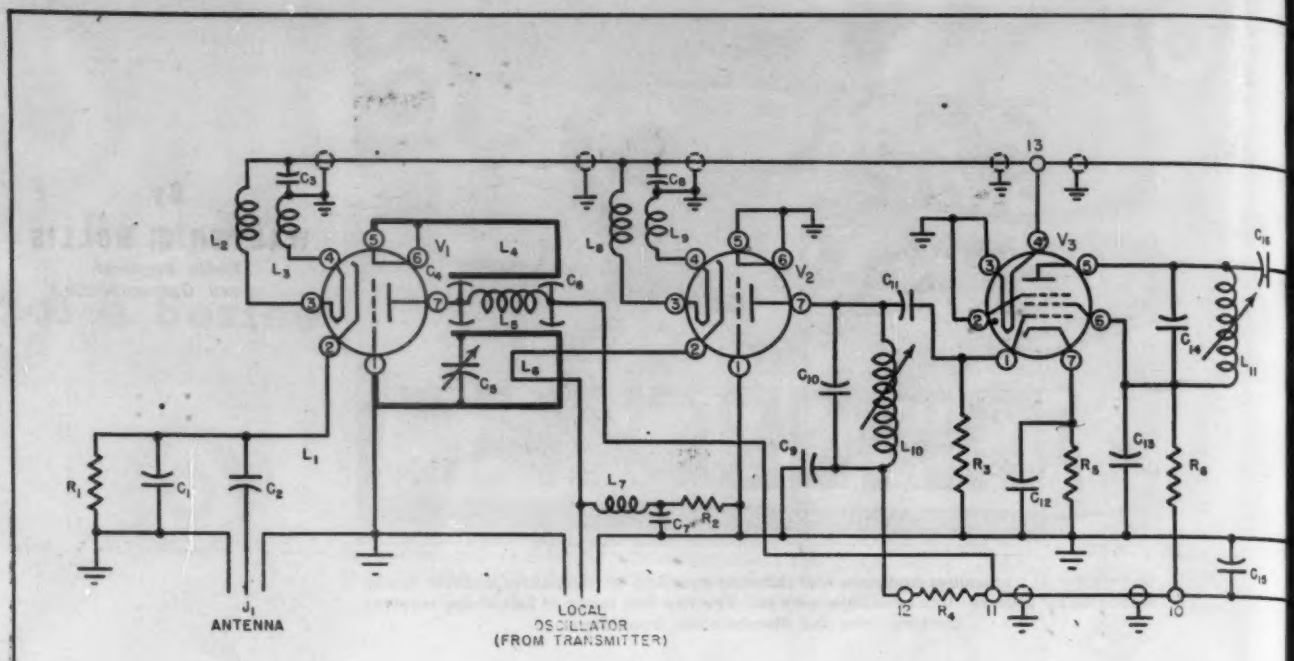


R_1, R_{14}, R_{16}–100, 1/2 w, Allen-Bradley
R_5–390, 1/2 w, Allen-Bradley
R_3, R_{15}, R_{24}–470,000, 1/2 w, Allen-Bradley
R_4–1,000, 1/2 w, Allen-Bradley
R_6, R_8, R_{11}, R_{18}–130, 1/2 w, Allen-Bradley
R_8, R_9, R_{12}, R_{19}–7,500, 1/2 w, Allen-Bradley
R_7, R_{10}, R_{17}, R_{20}–50, 1/2 w, Allen-Bradley
R_{13}–30,000, 1 w, Allen-Bradley
R_{21}–22,000, 1/2 w, Allen-Bradley
R_{22}, R_{23}–100,000, 1/2 w, Allen-Bradley

C_1, C_3, C_4, C_6, C_7, C_8, C_{37}–1,000 $\mu\mu$f, Erie button mica, Type 370BB
C_2–10 $\mu\mu$f, silvered mica
C_5–3–15 $\mu\mu$f, E. F. Johnson, type 160–107
C_9, C_{13}, C_{13}, C_{16}, C_{17}, C_{18}, C_{20}, C_{22}, C_{23}, C_{24}, C_{27}, C_{28}, C_{29}, C_{30}, C_{31}, C_{32} –5 $\mu\mu$f, Centralab Type D6–502
C_{10}, C_{14}, C_{19}–36 $\mu\mu$f, silvered mica
C_{11}, C_{16}, C_{21}, C_{26}, C_{33}–430 $\mu\mu$f, silvered mica
C_{25}–20 $\mu\mu$f, silvered mica
C_{34}–3 $\mu\mu$f, silvered mica
C_{35}, C_{36}–100 $\mu\mu$f, silvered mica

FIG. 2—Detailed circuit of the receiver showing values of compo-

L_1. Capacitor C_2 is provided for d-c blocking when used with an antenna or signal generator having a d-c return.

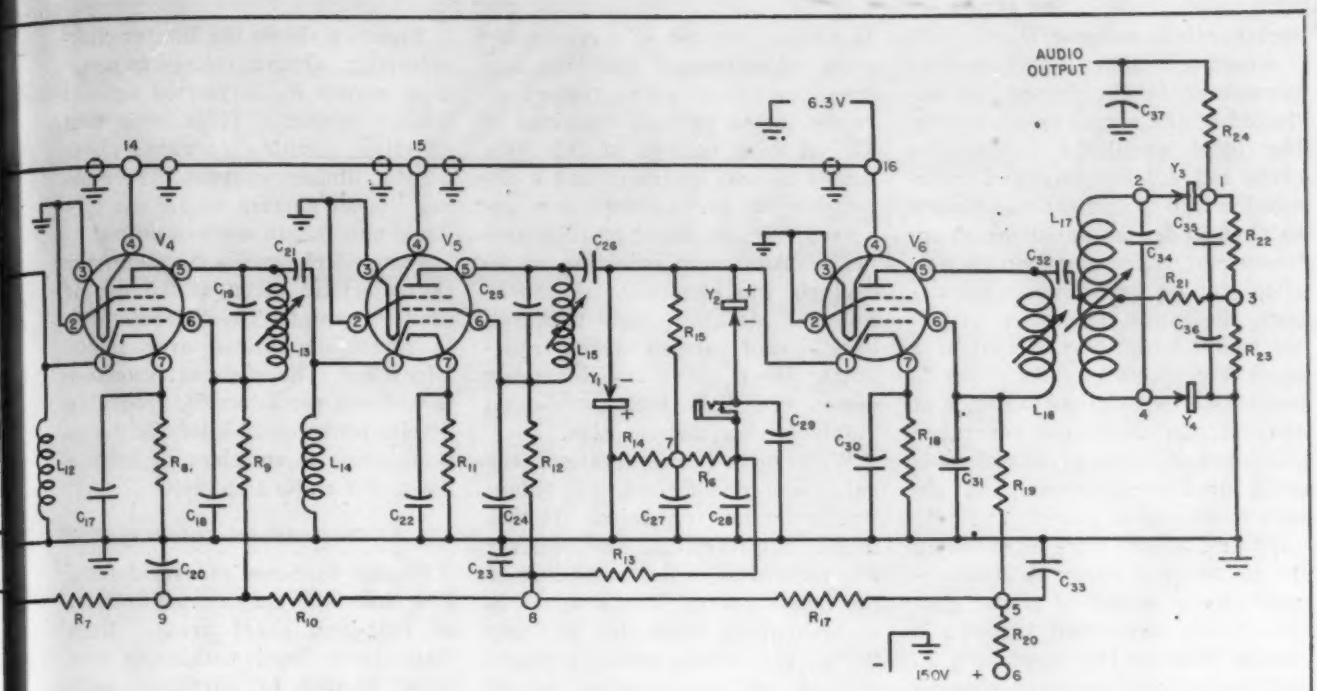
The plate resonator circuit for the grounded grid preamplifier consists of L_4 and C_5. These constitute a resonator similar to that used in the transmitter and shunt fed through L_6, C_4, and C_6. Grid bias is supplied by R_1, bypassed by C_1. Chokes L_2 and L_3, bypassed to ground by C_3, place the filament at cathode potential.

The converter, V_2, is another 6J4 operated with grounded grid. The amplified signal is inductively coupled from the preamplifier plate resonator through coupling loop L_6. Local oscillator power is fed in series with the amplified signal. The oscillator voltage is developed across self-resonant choke, L_7. Grid bias is developed across R_2 bypassed by C_7. Local-oscillator power is fed in at half frequency (225 mc) and doubling is accomplished in the converter.

The intermediate frequency of 15 mc is developed in the plate resonant circuit, L_{10}, C_{10}. Plate decoupling is accomplished by R_4, C_9. The i-f signal is coupled into the grid of the first i-f amplifier, V_3 through C_{11}, R_3. Tube V_3 is a 6AU6 operating as a normal pentode amplifier. The amplified i-f signal is developed across L_{11}, C_{14}. Plate decoupling is accomplished by R_6 C_{13}; grid bias is developed across R_5 bypassed by C_{12}. Coupling to the second i-f stage is through C_{16}, L_{12}. The second and third i-f stages, V_4 and V_5 are identical with the first. Inductors L_{13} and L_{14} are self-resonant grid chokes employed to provide zero audio gain to overcome a troublesome audio oscillation due to feedback through the plate decoupling networks.

The signal level in the third i-f plate circuit L_{15}, C_{25} is sufficient for limiting. The limiter is coupled through C_{26} and R_{18}, and consists of two 1N35 diodes oppositely biased to 0.5 volt through the voltage drop across R_{14} and R_{16}, bypassed by C_{27} and C_{28} respectively. A dropping resistor R_{12} limits the current to 5 ma. A closed circuit jack is used for limiter current monitoring; C_{29} bypasses it to ground.

The fourth i-f amplifier, V_6, is



L_1, L_4, L_8–see text
L_2, L_3, L_5, L_6, L_7–12 turns No. 22 enamelled, close-wound on 1/2-watt Allen-Bradley resistor, 100,000 or larger, dipped in Glyptal
L_9–15½ turns No. 22 enamelled, close-wound on 1-watt Allen-Bradley resistor, 100,000 or larger, dipped in Glyptal
L_{10}, L_{11}, L_{13}, L_{15}–16 turns, No. 30, heavy Formvar, close-wound on Millen form No. 69041
L_{12}, L_{14}–100 turns, No. 34 heavy Formex close-wound on Stackpole G–Y core, 0.25 x 7/8", coated with Glyptal
L_{16}–24 turns, No. 22 enamelled, close-wound on National XR–50 form
L_{17}–Bifilar winding, each winding 10 turns No. 26 heavy Formvar, double spaced
Feed-through terminals 1 to 16–Vitro-seal Corp. Terminal No. 1901–9–L-HT
J_1–UG–58/U r-f jack
J_2–Closed-circuit phone jack
V_1, V_2–6J4
V_3, V_4, V_5, V_6–6AU6
Y_1, Y_2, Y_3, Y_4–IN35 crystal

nents. At current net prices, the cost of parts is approximately $40

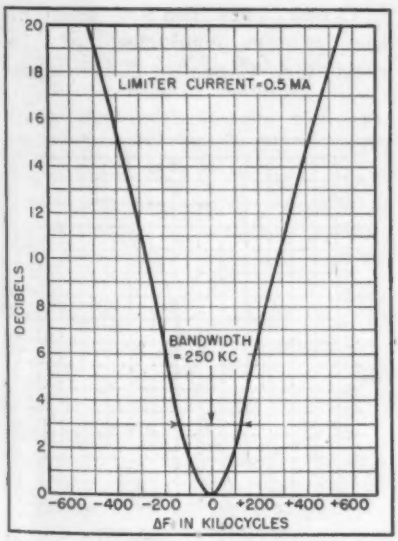


FIG. 3—Bandpass characteristic of the receiver i-f stages

driven by limited voltage. The output voltage is developed across L_{16}. This output voltage drives a Foster-Seeley discriminator consisting of L_{17}, C_{35}, Y_3, Y_4, R_{22}, R_{23}, C_{36}, C_{37}, and coupling elements C_{34} and R_{21}. Units Y_3 and Y_4 are 1N35 diode detectors. Opposing output voltages are developed across R_{22} and R_{23}. An inverse frequency network for reception of a phase-modulated carrier is formed by R_{24} and C_{37}.

Plate decoupling between stages is accomplished through R_{17}, C_{29}, R_{19}, C_{30}, R_7, C_{16}, and R_4, C_9. The filter formed by R_{20} and C_{33} effectively decouples any resonance in the plate supply.

As shown in the photographs the receiver chassis measures only 12¾ × 2¼ inches. All tubes and components are miniature. Each stage is individually shielded and the preamplifier plate resonator is built into the chassis. All i-f coils are slug-tuned and accessible for tuning from the top of the chassis, except for the discriminator coils which are accessible from the rear.

Performance

The assumed preamplifier and converter gain were not achieved. For the optimum adjustment of the r-f portion of the receiver, there are at least four interacting parameters to adjust. These are (1) output loop size, L_9, which directly affects (2) the tap position on L_1, and (3) local-oscillator drive power, a function of (4) the con-

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verter cathode resistor, R_2.

Another difficult-to-determine parameter is the impedance reflected at the signal frequency by the local oscillator across the choke coil, L_7. The length of transmission line (5 inches) was chosen so that under assumed maximum limits of terminating loop inductance (tap on first doubler resonator), the input impedance at 465 mc would be a short circuit or a capacitive reactance. As choke L_7 presents a capacitive reactance at 465 mc, an inductive reactance presented at input to coaxial cable could produce resonance and absorb much signal power.

The r-f stages were adjusted in the following manner: A Measurements Corp. model 84 signal generator was connected through a coaxial cable to the input jack J_1 and an 0-1 milliammeter plugged into J_2. A loop size was chosen for L_6 and the local oscillator adjusted to produce a computed bias of 5.8 volts across R_2. With sufficient output voltage from the signal generator to produce limiter current, the preamplifier tuning adjustment, C_{10}, was adjusted for maximum limiter current. The local oscillator tuning was then adjusted for maximum limiter current. Several tap positions were then tried and the signal generator level for minimum detectable limiter current noted. This process was repeated for other loop sizes for L_6. This process admittedly adjusts for maximum gain, not signal to noise ratio.

A loop size of $1\frac{5}{8}$ by $\frac{3}{4}$ inch made of No. 14 tinned copper wire for L_6 was determined as a reasonably good adjustment. For this size loop, the antenna was tapped directly to the cathode terminal of V_1. A bias voltage of 3.5 volts across R_2 was optimum and a detectable limiter current was observed from an input of 10 microvolts. An image rejection of 30 decibels was observed. A bench-to-bench talking test using a bread-board version of the transmitter described in the November issue of ELECTRONICS showed highly intelligible reception.

With no i-f regeneration, the gain was insufficient to obtain limiter current on noise. It was found, however, that the receiver was critical as to the grounding of the shield cover. The receiver is normally quite stable, but at times it was possible to obtain a slight amount of regeneration which brought the noise up to a readable level. Under these conditions, assuming no decrease in i-f bandwidth, the noise figure measured 20 decibels above theoretical.

Figure 3 shows the i-f bandpass characteristic. This was measured by feeding an i-f signal in at the local oscillator input. Under this condition, the converter stage operates as an i-f amplifier. This has a minor effect due to differences in the plate resistance between converter and amplifier operation. For this measurement, the limiter current was maintained constant at 0.5 ma. The ratio of input voltage expressed in decibels is plotted against deviation from the center frequency. The bandwidth for 3-db down is 250 kc, the objective.

Figure 4 shows the limiter characteristic. Output voltage as measured across R_{23} is plotted against limiter current. It is seen that effective limiting occurs above 0.1-ma limiter current. Increasing limiter current to 1.0 ma produces only 3.3-db more in output.

Figure 5 shows the discriminator characteristic taken at 0.5 ma of limiter current. The characteristic is essentially linear over ± 100 kilocycles. The slope at resonance is 0.08 volt per kilocycle, producing 2 volts peak for 25-kilocycle deviation, which is sufficient to drive a low-power audio amplifier.

Constructional Details

Figure 6 shows chassis details. The chassis is constructed entirely of 1/32-inch sheet brass. Each stage is enclosed within its own shield formed by partitions soft-soldered into the chassis. Each partition has a cut-out to clear the tube socket. The preamplifier plate resonator is formed by two partitions, into one of which a $1\frac{1}{8}$-inch length of $\frac{1}{4}$ inch $\times$ 1/32-inch wall brass tubing is soldered.

A shield cover of 1/32-inch sheet brass is securely fastened to the chassis with 3–48 screws. Two screws are used in each partition to produce a complete electrical shield between each stage. The chassis and cover are cadmium plated to resist corrosion.

Button mica capacitors and feed-through terminals are soft-soldered into the plated chassis. Units C_4 L_5 and C_5 are then assembled into the center conductor of the resonator. Capacitor C_5 is mounted

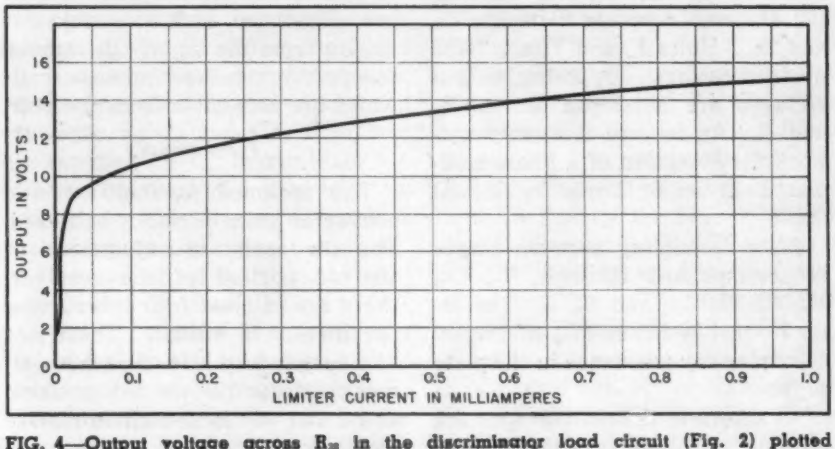

FIG. 4—Output voltage across R_{23} in the discriminator load circuit (Fig. 2) plotted against limiter current

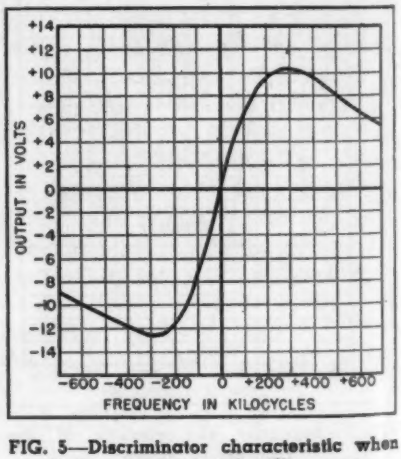

FIG. 5—Discriminator characteristic when limiter current is 0.5 milliampere

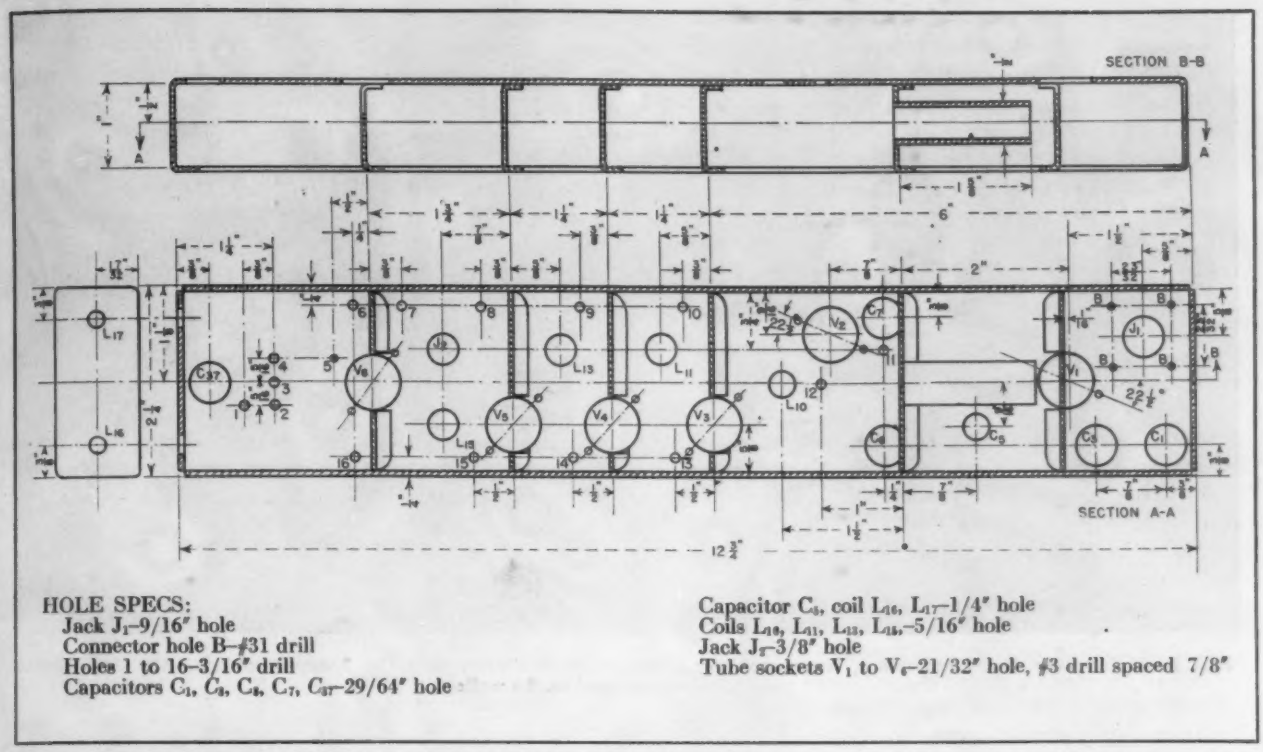
SECTION B-B
SECTION A-A
HOLE SPECS:
Jack J1–9/16" hole
Connector hole B–#31 drill
Holes 1 to 16–3/16" drill
Capacitors C1, C2, C4, C7, C37–29/64" hole
Capacitor C3, coil L16, L17–1/4" hole
Coils L10, L11, L13, L15,–5/16" hole
Jack J2–3/8" hole
Tube sockets V1 to V6–21/32" hole, #3 drill spaced 7/8"

FIG. 6—Mechanical details of receiver chassis, including those of shield partitions. Section A-A at the right is the plate resonator of the r-f preamplifier stage

on the chassis and the uprights soldered to the center conductor. Coil L_1 is a length of No. 14 tinned copper bus wire spanning the cathode terminal of V_1 and the terminal on C_1. It is spaced about ¼ inch above the chassis.

The components should next be mounted and the receiver wired in the normal manner. All grounds are made to the same point within each stage; for example, C_{12}, C_{13}, C_{15}, and L_{12} are all grounded to the same point as terminals No. 2 and No. 3 on the tube socket for V_3, grounded to shield partition.

The secondary winding of the discriminator transformer, L_{17}, consists of two interlaced windings spaced one wire diameter. One set of opposite ends of the winding are tied together to form the center tap. The other set of opposite ends feed the 1N35 crystal diodes. This construction automatically permits the tuning slug to affect both windings nearly equally, thus maintaining an approximate inductance balance.

All shielded filament and plate leads are covered by copper-shielded wire, Precision Tube Co., No. 22 Lenz Aeroglas, in 0.101 OD by 0.009 wall tubing.

A signal generator tuned to 15 mc is connected to the local oscillator cable. Care must be taken to carefully shield this lead. A 0–1 ma meter is plugged into J_2. Coils L_{10}, L_{11}, L_{13}, and L_{15} are tuned for maximum meter current. A high resistance d-c voltmeter is next connected from terminal No. 3 to ground and L_{16} tuned for maximum deflection. The voltmeter lead is then moved from terminal No. 3 to No. 1 and L_{17} adjusted for a null. This completes the i-f alignment.

A signal generator is next connected through a coaxial cable to the input jack, J_1. Local oscillator power at 225-mc (4,166.667-kilocycle crystal) is fed in through the local oscillator coaxial cable by tapping the center conductor of the cavity resonator of the first doubler stage of the transmitter through a 10-$\mu\mu$f. mica capacitor, see Fig. 2.

The local oscillator power is adjusted to produce 3.5 volts across R_2 by adjusting the tap position or tuning of the first doubler of the transmitter.

One possible improvement, requiring no circuit change, is a reduction in the resistance of R_2. The value of 390 ohms was computed on the basis of maximum second harmonic space current at a d-c cathode current of 15 ma. An optimum bias voltage of 3.5 corresponding to 9-ma cathode current was observed. This indicates increased conversion transconductance could be achieved by reducing the value of R_2, staying within maximum plate dissipation (2.25 watts) of the 6J4.

Another relatively simple improvement would be to change the 6J4 converter into a 15-mc grounded-grid amplifier. The input impedance would present approximately the optimum load for a silicon crystal converter which could be incorporated into the preamplifier resonator.

Acknowledgments

The author wishes to thank Herbert Hardy for his assistance in the mechanical construction of the chassis. Thanks are also due Gilman Andrews for his suggestions and criticisms during the design and test of the receiver.

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FIG. 1—In this view of the laboratory, the central test equipment racks illustrated in Fig. 2 appear at left. The line-isolation amplifiers are mounted on the walls

Television Receiver Laboratory

Design of test facilities, shielding, and filtering for a development laboratory. An oscilloscope adapter, line-isolating amplifiers, safety boxes for c-r tubes and the construction of the shielded room are among the features

By FRANK R. NORTON

Principal Research Engineer
Bendix Radio Division
Bendix Aviation Corporation
Baltimore, Maryland

IN THIS PLANT, the television receiver development program is carried out in part in the general laboratory area, with the main activity taking place in a special receiver room, a small camera room, two shielded rooms, and an adjacent space with impedance-measuring lines suitable for use at 40 mc to 250 mc.

The main television room is shown in Fig. 1. In addition to a number of 7, 10 and 15-inch direct-view receivers and one 10-inch indirectly-viewed experimental receiver, one 15 and two 10-inch diameter cathode-ray tubes may be seen on the benches in safety boxes. These are plywood boxes with sloping fronts, having a safety-glass window the full size of the tube screen. They are provided with readily adjustable deflection-yoke and focus-coil mounts.

In one safety box, a second focus coil and deflection yoke have been mounted remote from those around the neck of the tube. By switching from one set of coils to the other (with brightness control turned down to avoid burning a spot on the screen) the undeflected, unfocused spot can be conveniently observed. This is of interest in studying asymmetry of the spot or proper adjustment of the ion-trap magnet. Connections to a receiver chassis can be made by using either binding posts or a multiple-pin connector mounted on the side of the box. The front section of the box is hinged and held

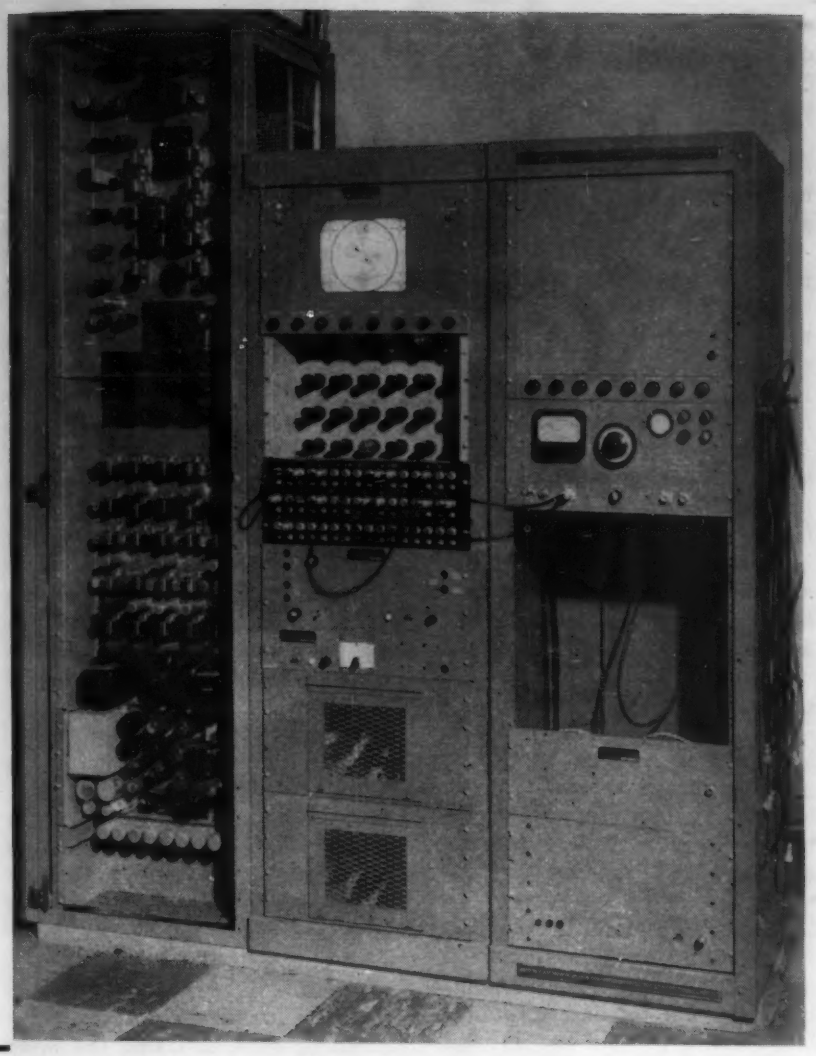

FIG. 2—Central receiver test equipment. The rack at left contains the sync generator. In the center rack are the laboratory picture monitor, distribution and line amplifiers, a linearity test generator, and picture monitor and monoscope camera power supplies. The right-hand rack mounts the monoscope, a transmitter, a noise generator, and line-isolation amplifier power supply

in place by convenient snap catches to facilitate changing tubes.

Curtains are provided for darkening one end of the room without affecting the rest of the laboratory. Fluorescent ceiling units provide over 20 foot-candles of illumination. Lights behind the curtains can be turned off separately, and, if desired, an incandescent unit in that area can be adjusted from its maximum light output to any lower brightness by means of a Variac.

Test Instruments

The first essential equipment of a television laboratory is a television synchronizing generator, preferably one complying with RMA standards[1]. The second major requirement is a dependable source of picture signals such as those obtained from a monoscope or other test pattern which remains fixed while adjustments are made and which can always be used to observe the geometric distortion, resolution, contrast, focus and general quality of the received picture.

An electrical bar or grating pattern generator is needed to accurately and rapidly adjust sweep linearity. The pattern generator signals provide a grating of horizontal and vertical bars accurately spaced in time. Thus their distances apart on the picture screen show the sweep speed averaged over each time interval between bars. The pattern can be chosen so as to produce squares when the aspect ratio is correct and then the linearity and amplitude of the sweeps can be quickly adjusted.

A monoscope camera (such as the one at the top of the right hand rack in Fig. 2) generally includes an amplifier which mixes blanking signals with the picture signal. Either its output or that of some other camera or picture signal source is then put into a line amplifier where sync pulses are added to produce a standard RMA[2] composite picture signal. This composite video signal should then be monitored by a laboratory picture monitor and a waveform monitor. For complete receiver testing, a laboratory television transmitter is necessary if locally broadcast picture signals are not available.

A noise generator to provide a known and controllable amount of various types of noise, such as thermal noise, but more particularly impulse noise similar to ignition noise, is also needed to permit study of noise limiting and sync interference and other important receiver characteristics.

In Fig. 2, the RMA sync generator occupies the left-hand rack. Its outputs are made available both on the central racks and at seven line-isolation amplifiers mounted in boxes on the wall above the benches at convenient locations around the laboratory. These locations are connected through RG 59/U coaxial lines to the central racks. The coaxials and d-c power connections for each line-isolation amplifier are run in ducts mounted along the walls near the ceiling with branches down to each box. From each box two coaxial cables run directly to the central jack panel shown at the center of Fig. 2. Signals can be sent from any part of the room to any other location by making a suitable connection at the jack panel. This saves time and avoids having lines remain on the floor.

The picture on the monitor at top center of Fig. 2 is not retouched. The actual picture resolution and contrast as viewed directly are excellent, even with the room brightly lighted. An aluminized 10-inch cathode-ray tube is used at about 14 kilovolts, giving about 200 foot-lamberts brightness in the highlights. A neutral density filter in

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the safety glass over the tube has only 40-percent light transmission. The ambient room illumination is thus attenuated before it strikes the screen. Thus the picture still looks bright and the contrast is not appreciably impaired when the room is fully lighted.

A small broadband scope near the racks is used as a waveform monitor and doubles as a test oscillograph. However, it is desirable to have a rack-mounted waveform monitor which is always available when needed.

The test transmitter shown on the right-hand rack in Fig. 2 is crystal controlled for the desired channel. The output stage uses a grid-modulated 832A tube with a 2-inch c-r monitor directly connected to the plate coil. A balanced mutual-inductance type attenuator is used, giving a continuously adjustable output from 100,000 to 1 microvolt with a direct-reading dial. This balanced output appears on two coaxial jacks, at an impedance level of 50 ohms to ground from either side, or 100 ohms from side to side. This is very convenient in receiver testing.

Line-Isolation Amplifiers

The line-isolation amplifiers shown in the schematic of Fig. 3 have five type 6J6 tubes, one for each of the five independent circuits. Both plate and cathode-coupled outputs (either polarity of the applied signal) are available at coaxial jacks on the front of the box. The first three circuits are intended for pulse signals such as sync, blanking, camera driving, and the last two for composite picture signals or camera output signals. Slightly different circuit values were used for convenience.

The polarity of the input signals on the first and last circuits are black negative so the output jacks are marked — on the cathode and + on the plate to indicate the output signal polarity. The middle three circuit jacks are marked with the + on the cathode and — on the plate to indicate whether the output is the same or the opposite polarity from the applied input.

The maximum output level is about 0.5 volt peak-to-peak if compression is to be avoided. This level is often insufficient, but a few booster amplifiers used on the bench as needed have been found satisfactory. Other engineers may prefer to use more distribution amplifiers whose outputs can be patched from central racks to any location desired. This line-isolation amplifier system provides a multiplicity of outputs always available at each location. Larger output tubes were not used because the total B current drain of the isolation amplifiers would become excessive.

The coaxial line to the amplifiers is looped into one after another, the amplifier inputs being simply bridged across the line except at the last amplifier, where the line must be accurately terminated to avoid reflections which may become serious if there is an appreciable mismatch. A small coaxial cable of the length used here has about 3-db loss at 5 mc. The output of the amplifiers is practically flat to beyond 5 mc except for the line loss, which is not serious since the phase response is excellent.

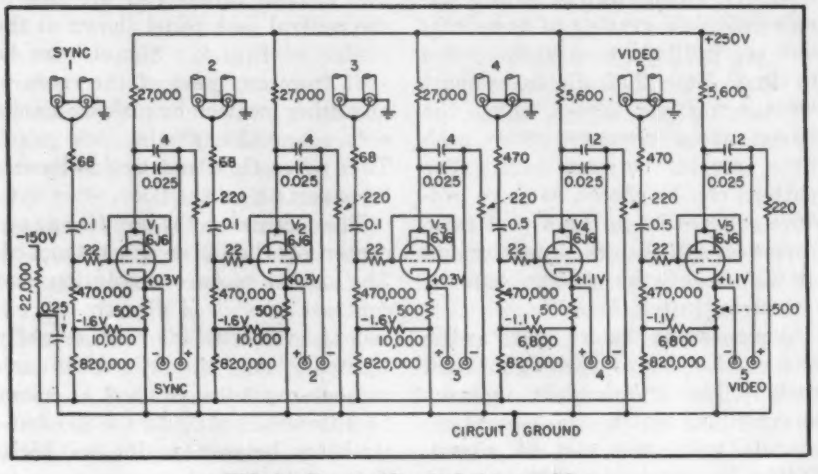

FIG. 3—Circuit of line-isolation amplifier

Oscilloscope Adapter

An oscilloscope adapter is shown in Fig. 1 on the rear bench at the left-hand side. It may be conveniently used with any broad-band oscilloscope to increase its utility in television development work. Its schematic diagram is shown in Fig. 4. The adapter is used to supply a 60-cycle calibrating voltage to the input probe to compare in amplitude with the signal under test, and to supply a variable sweep voltage to provide sufficient sweep velocity to view only a few lines of a television signal. This is also adjustable in phase; any desired portion of the signal may be expanded for close examination. The unit also provides a double trace on the oscilloscope at a 30-cycle rate for study of the interlace of a television signal, and provides a broadband (6-mc) video mixing amplifier with two inputs.

The sweep-voltage waveform is a trapezoid, produced from a 60-cycle sine wave which is adjustable in phase over about 360 degrees. The slope or velocity may be varied to allow only a few lines of a television signal to be viewed if desired. Blanking for the oscilloscope is produced by differentiating the sweep to avoid bright spots on the screen where the beam would otherwise dwell during the time between the fast sweep intervals.

In using the unit, compression of the positive trace may occur due to nonlinearity in the amplifier if the trace separation is widened too far. The phase shifter is quite satisfactory but an autosyn resolver would give even more constant output amplitude and make it possible to adjust the phase continuously in any direction. The present arrangement is limited to 360 degrees and has a slight variation in amplitude with phase.

Shielded Rooms

The screen rooms are somewhat unusual in that hardware cloth with ¼-inch mesh is used for both the inner and outer screens on the usual wooden 2 × 4 frames. The relatively open mesh permits excellent interior illumination by

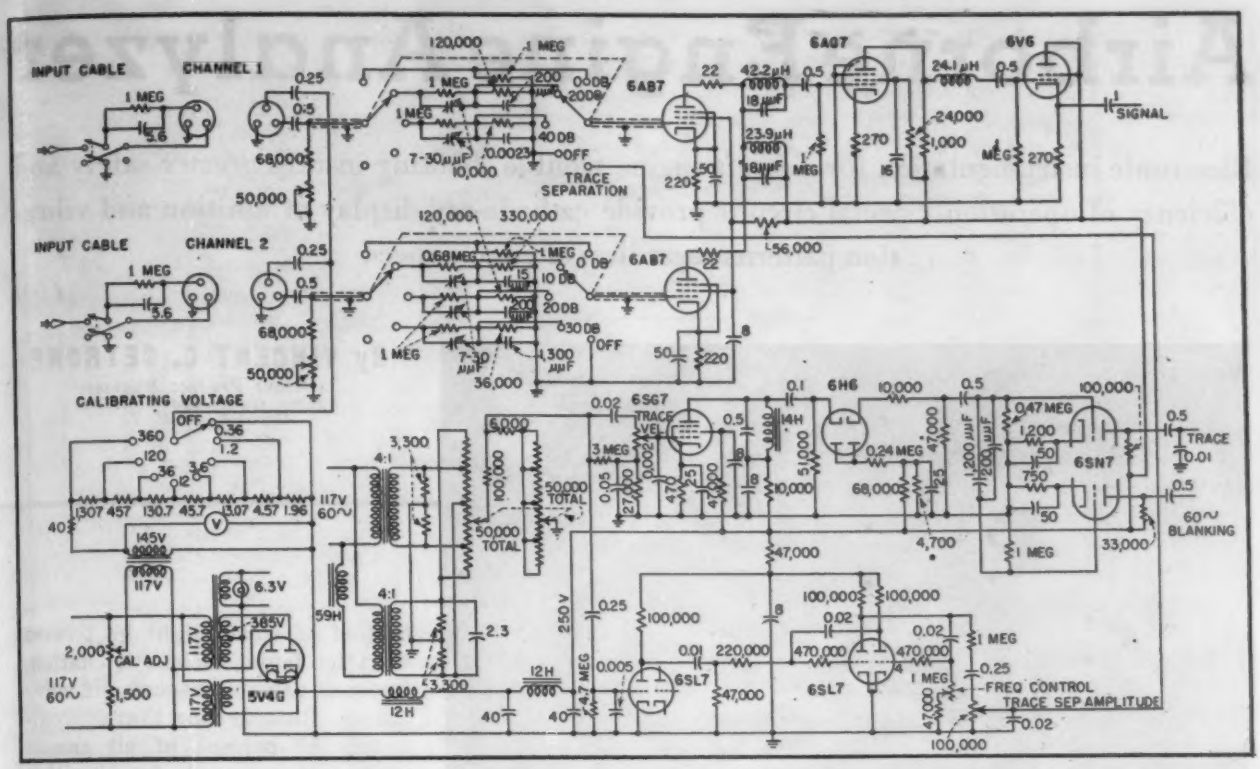

FIG. 4—Circuit of oscilloscope adapter

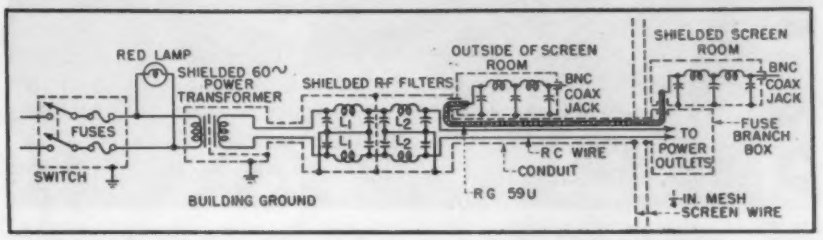

FIG. 5—Power line and video input filters for the shielded room

fluorescent light fixtures suspended just over the enclosure, thus eliminating any radio interference due to them and not loading the special filtered power circuit to the room. The open mesh also permits a free circulation of fresh air from an anemostat over the screen room.

The galvanized steel wires of the hardware cloth are bonded at every intersection, and it is believed that the efficiency of the screen in eliminating radio interference will be higher over a period of years than for a fine mesh copper screen, which is likely to corrode in time and cause poor contact between wires.

In constructing the rooms, care was exercised to solder all joints in the hardware cloth. Joints around the door between the screen on the door and that on the main frame are doubly sealed by bronze weather-stripping on both the door and the frame, on both the inner and outer sides. No connection anywhere between the inner and outer screens was permitted except for the single conduit which carries power wires and coaxial cable circuits.

A schematic of the filters for one of the screen rooms is shown in Fig. 5. With this arrangement the screen room provides more than 70-db attenuation anywhere within the room with respect to a signal level measured just outside the room, throughout the frequency range from 20 to 250 mc.

The main power fuse and switch box for each room is mounted outside the door, with a red lamp to indicate when the power is on. The 60-cycle shielded transformer and all the wiring are enclosed in metal boxes or conduit. A motor-driven voltage regulator supplies a constant 117 volts.

The two r-f filter sections are made resonant at widely different frequencies, and seem to be quite effective throughout the spectrum. Chokes L_1 and L_2 in the r-f filters are multiple-layer solenoids wound with large rectangular wire to avoid heating and keep the line voltage drop low.

Two coaxial lines into the screen room (only one is shown in the schematic) have 15-mc low-pass filters in small boxes on both the outside and the inside of the room. Thus any video signals (including color picture signals) can be transmitted without distortion of the signal and without any interference being introduced into the screen room at present television i-f or carrier frequencies.

The author wishes to acknowledge the contributions made by many engineers and technicians associated with him, particularly those of W. B. Wilkens and J. E. Mackenzie, and the encouragement and assistance of A. C. Omberg, chief research engineer.

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(2) Report of Sub-Committee on Studio Facilities, (above) and drawing, Picture Line Amplifier Standard Output, Oct. 9, 1946. RMA Data Bureau.

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Airborne Engine Analyzer

Electronic instrumentation for aircraft engine trouble shooting insures greater safety and efficiency of operation. Special circuits provide cathode-ray display of ignition and vibration patterns regardless of engine speed

By VINCENT C. CETRONE
Assistant Product Engineer
Sperry Gyroscope Co., Inc.
Great Neck, N. Y.

Engine analyzer installed in plane at rear of pilot's seat near flight engineer's desk

ALTHOUGH many engine malfunctions are not serious enough to prevent aircraft from flying, present-day commercial practice requires that all engines on even multi-engine ships be in as nearly perfect condition as possible before the plane is permitted to take off.

As a result of these high standards of maintenance, and because no easy, accurate, and rapid method has been devised to enable maintenance crews to quickly locate engine malfunctions, airlines have often found it necessary to withhold an aircraft from active service for many hours and even days because one or more causes of engine irregularities could not be located.

Estimates of the loss in revenue to an airline caused by the grounding of a large ship range as high as $37,000 per day.[1] Although in some cases this constitutes merely a paper loss it is none the less true that the dollar loss caused by an aircraft being grounded is considerable, and when added to the passenger ill-will invariably incurred when flights are delayed or cancelled the situation becomes of considerable importance to any first-class airline.

The importance of the problem has been recognized for some time, and much work has been done in the development of methods designed to expedite maintenance work to the utmost.

Functions Performed

The two principal functions of the engine analyzer[2] are: the location and identification of engine ignition system malfunctions such as fouled plugs, faulty magneto capacitors, and grounded high-tension leads; and the location and identification of what might be termed vibration faults, such as detonation, incorrect valve clearances, and valve bounce. Records show that approximately 50 percent of all engine faults are caused by ignition troubles alone.[3]

It should be noted that the engine analyzer is installed as a permanent part of the aircraft's flight equipment and consequently is available not only to the maintenance crews while the ship is on the ground, but is also constantly available to the flight engineer so that he can check the power plant whenever he has an opportunity or whenever he believes a fault is developing. Experience has shown that checks made during actual flight often reveal faults not detectable by ground test methods.

Ignition Check

To understand how ignition faults are revealed it is necessary to discuss the operation of a typical aircraft-engine ignition system.

Without considering the details involved, we can state that at the instant the magneto breaker points are opened by the engine-driven magneto cam mechanism, a high value of magnetic flux has been built up in the iron core structure of the magneto by the action of the magneto's permanent magnet rotor. Then as the breaker points separate, this magnetic field suddenly collapses, generating a very high voltage in the secondary winding of the magneto which is connected to the

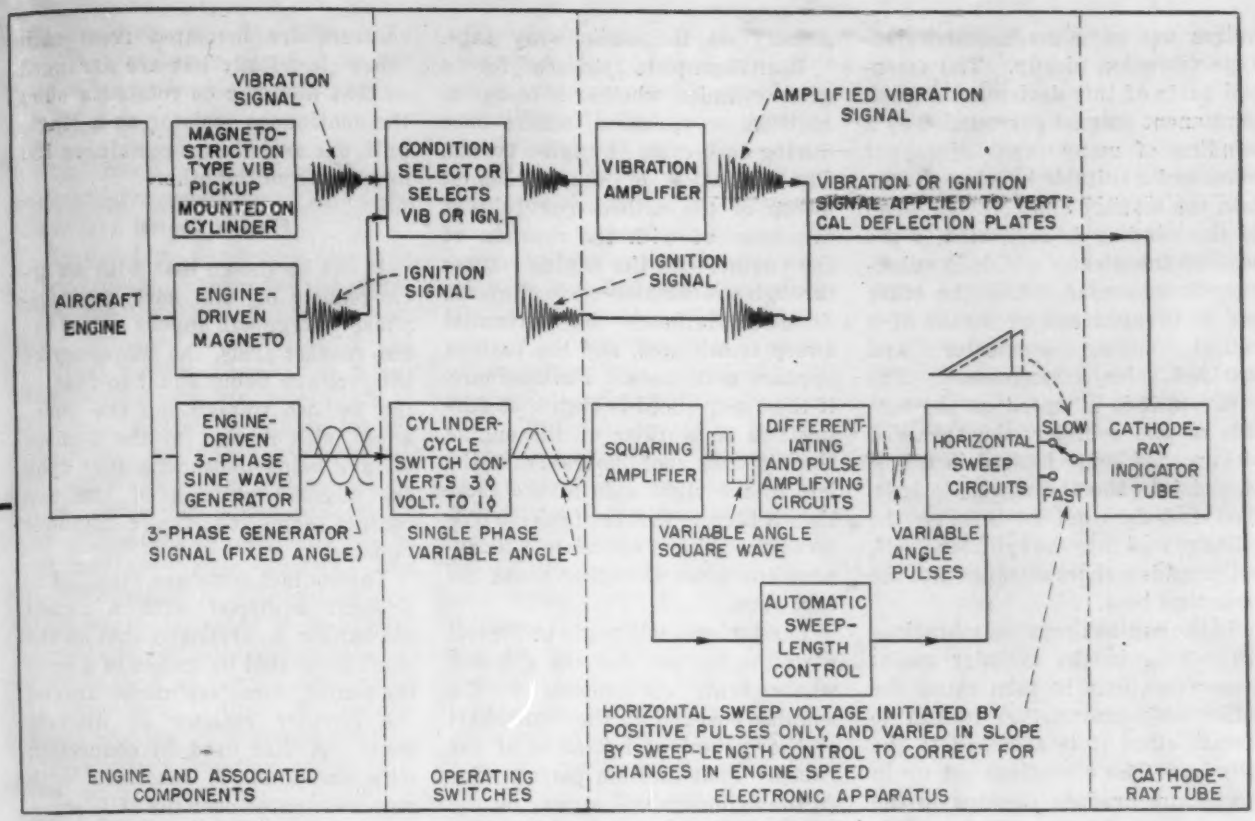
VIBRATION SIGNAL
MAGNETO-STRICTION TYPE VIB PICKUP MOUNTED ON CYLINDER
CONDITION SELECTOR SELECTS VIB OR IGN.
VIBRATION AMPLIFIER
AMPLIFIED VIBRATION SIGNAL
VIBRATION OR IGNITION SIGNAL APPLIED TO VERTICAL DEFLECTION PLATES
AIRCRAFT ENGINE
ENGINE-DRIVEN MAGNETO
IGNITION SIGNAL
IGNITION SIGNAL
ENGINE-DRIVEN 3-PHASE SINE WAVE GENERATOR
CYLINDER-CYCLE SWITCH CONVERTS 3 ϕ VOLT. TO 1 ϕ
SQUARING AMPLIFIER
DIFFERENTIATING AND PULSE AMPLIFYING CIRCUITS
HORIZONTAL SWEEP CIRCUITS
SLOW
FAST
CATHODE-RAY INDICATOR TUBE
3-PHASE GENERATOR SIGNAL (FIXED ANGLE)
SINGLE PHASE VARIABLE ANGLE
VARIABLE ANGLE SQUARE WAVE
VARIABLE ANGLE PULSES
AUTOMATIC SWEEP-LENGTH CONTROL
HORIZONTAL SWEEP VOLTAGE INITIATED BY POSITIVE PULSES ONLY, AND VARIED IN SLOPE BY SWEEP-LENGTH CONTROL TO CORRECT FOR CHANGES IN ENGINE SPEED
ENGINE AND ASSOCIATED COMPONENTS
OPERATING SWITCHES
ELECTRONIC APPARATUS
CATHODE-RAY TUBE

FIG. 2—Block diagram of engine analyzer

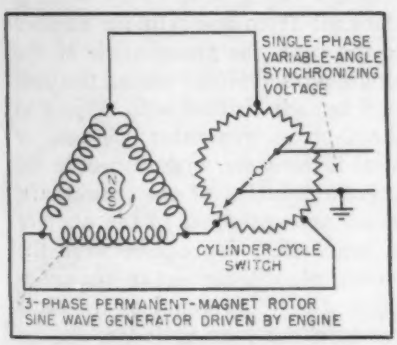
SINGLE-PHASE VARIABLE-ANGLE SYNCHRONIZING VOLTAGE
CYLINDER-CYCLE SWITCH
3-PHASE PERMANENT-MAGNET ROTOR SINE WAVE GENERATOR DRIVEN BY ENGINE

FIG. 1—Simplified circuit diagram of synchronizing voltage generator

spark plugs through the distributor. It is this voltage that fires the spark plugs.

During the time that the breaker points are open and the spark discharge is taking place the engine analyzer makes its analysis of conditions existing in the ignition system. The spark discharge sets into motion a highly oscillatory circuit. This circuit comprises the resistance and inductance of the magneto primary as well as the primary capacitance located in parallel with the breaker points. The circuit also includes the resistance, inductance and stray capacitance of the secondary circuit, including the effect of ionization in the spark-plug gap, and the breakdown and extinction voltages of the plug. The characteristics of the oscillation will be determined by these quantities and it follows that if one of them, say the secondary resistance, should change from its normal value to some higher or lower value, then the resulting oscillation would suffer a change in one or more of its characteristics such as its frequency, or rate of damping.

It has been found that in ignition systems nearly all of the common malfunctions are accompanied by some significant change in one or more of the electrical parameters constituting the oscillatory circuit. Consequently, it is necessary only to establish the oscillation characteristics occurring in a completely normal engine, and then to establish, similarly, the characteristics produced by the various ignition malfunctions. The effect of the malfunctions upon the oscillation characteristics have been studied by building in various faults such as fouled plugs on a test engine.

Breaker-Point Voltage

In order to study the oscillations, it is necessary to specify a method of measuring them. In the engine analyzer this is done by measuring the voltage appearing across the breaker points during the time they are open, and the actual evaluation of the characteristics is made visually by observing the resulting ignition patterns on a cathode-ray type indicator. The voltage across the breaker points is chosen because it rarely exceeds 200 volts.

It should be noted that an isolating resistor of several thousand ohms value is placed between one of the magneto breaker points (the other breaker point being grounded in a normal engine installation) and the analyzer. This resistor prevents any short circuit or ground condition that might occur inside the analyzer from affecting the operation of the magneto.

Analysis of vibration faults re-

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quires use of a magnetostriction-type vibration pickup. The essential parts of this device are a small permanent magnet surrounded by a winding of many turns of copper wire, and a suitable housing to contain the magnet and coil. One end of the winding is connected to the case of the pickup which is subsequently grounded, while the other end is brought out by means of a helical spring connector and shielded cable arrangement. The entire unit is mounted on the outside of the cylinder, the threaded pickup stud being located in a hole tapped into the thermocouple boss. The stud does not go through the cylinder wall into the cylinder itself, but extends a short distance into the mounting boss.

As the engine operates, vibrations are set up in the cylinder walls; these vibrations in turn cause the entire magnetostriction pickup to vibrate since it is attached to the cylinder. The vibrations set up in the pickup produce stresses in the permanent magnet, and since this magnet is made of a highly magnetostrictive metal, these stresses cause the magnetic flux of the magnet to vary in intensity, inducing a voltage in the winding surrounding the magnet. This voltage is equal in frequency to the frequency of the vibration, and proportional in amplitude to the amplitude of the vibration. Consequently, by its strategic location on the engine cylinder, the pickup is able to produce a voltage which is characteristic of cylinder vibrations caused by detonation and valve bounce.

Sweep Requirements

To understand the operation of the analyzer it should be noted that there are two voltages that must be displayed on a cathode-ray tube screen. These are the voltage from the magneto breaker points, and the voltage from the vibration pickup. Each of these signals is applied to the vertical deflection circuit of the cathode-ray tube. This leaves only the horizontal circuit of the cathode-ray tube to be considered.

In order to examine either the ignition or vibration voltages, it is clear that the patterns formed by these voltages must appear stationary on the cathode-ray tube.

Each complete pattern for a given cylinder, whether it be due to ignition or vibration, occurs once during each cycle of engine events. The initiation of the horizontal sweep of the cathode-ray tube is synchronized with the rotation of the engine. As the engine rotates through one complete cycle of events (two revolutions) the horizontal sweep is initiated, and the pattern appears stationary. Furthermore, if the sweep speed is such that during two revolutions of the engine the electron spot moves from the left to the right side of the tube, then it is clear that the ignition patterns for all the cylinders will appear one after the other along the tube face.

The patterns will begin at the left with the pattern for the cylinder whose firing corresponds to the angular position of the crankshaft at the instant of initiation of the sweep. That ignition patterns for all the cylinders will appear on the screen is seen from the fact that in two revolutions of the engine the magneto breaker points must open a number of times exactly equal to the number of cylinders. One vibration pattern for one cylinder will occupy the entire length of the trace, since one complete vibration pattern requires two engine revolutions for its completion.

Figure 1 shows the circuit used in generating the signal which is ultimately used for initiating the sweep in proper synchronism with the engine. The generator is a small 3-phase permanent magnet alternator that is connected to one of the engine's auxiliary tachometer drives. The alternator is wound as a two-pole machine and hence delivers one complete cycle of alternating voltage per revolution of its rotor. Since the tachometer drive operates at half the engine speed, the frequency of the resulting 3-phase voltage in cycles per second is numerically equal to half the speed of the engine in revolutions per second. This 3-phase voltage is applied as shown to a continuous resistor wound uniformly in a circular configuration. The continuous resistor is arranged so that it is contacted at two points 180 degrees apart by two contact arms. These contacts are insulated from each other electrically but are arranged so that they can be rotated around the continuous resistor as a single unit, one arm always remaining 180 degrees from the other.

Phasing Control

It can be shown that with an arrangement of this sort a single-phase voltage will appear across the two contact arms, the frequency of this voltage being equal to that of the 3-phase voltage and the phase angle with respect to the 3-phase voltage being dependent only upon the angular position of the two contact arms on the continuous resistor.

The contact arms are attached to a shaft equipped with a detent mechanism so arranged that as the shaft is rotated by means of a knob the contact arms are moved around the circular resistor in discrete steps. A dial used in connection with the knob is inscribed with numbers spaced over the 360-degree travel of the knob, one number for each cylinder. The numbers of the cylinders appear around the dial in the sequence of the particular engine's firing order. By turning the knob from one cylinder number to the next, the phase angle of the single-phase voltage across the contact arms is shifted with respect to the 3-phase generator voltage, or what is the same, with respect to the angular position of the crankshaft, by an amount equal to the number of crankshaft degrees between the occurrence of an event in one cylinder and the occurrence of the same event in the next cylinder.

The circular resistor, the contact arms, and the knob and dial arrangement are assembled as one unit known as the cylinder-cycle switch. For a given setting of the cylinder-cycle switch, the phase angle of the single-phase voltage with respect to the crankshaft will remain fixed regardless of variations in engine speed. This requirement obviously must be met in the present application, and represents the principal reason for using this type of circuit rather than one of many possible arrangements in which the phase shift would be dependent not only upon the setting of one or more circuit parameters,

but would also be a function of the varying frequency supplied by the generator as engine speed varies.

Block Diagram

The block diagram of Fig. 2 shows the complete operation of the analyzer.

Three signals entering the analyzer from the engine are the vibration, ignition, and 3-phase generator voltages. The vibration and ignition signals go into the condition-selector switch, where either one or the other is chosen by the operator. If ignition is selected, the signal is passed to the vertical deflection circuit of the cathode-ray tube. Since the amplitude of the voltage appearing across the breaker points is sufficient to produce ample deflection when applied directly to the cathode-ray tube, no amplification of the ignition signal is necessary. If the vibration signal is selected, it is passed through the vibration amplifier and then to the cathode-ray tube. Amplification is necessary because the normal output of the vibration pickup is only a small fraction of a volt.

The single-phase sine wave developed from the 3-phase generator enters a squaring amplifier followed by a differentiating and amplifying circuit that converts the square waves into one positive and one negative pulse each cycle. The positive pulses are used to trigger the horizontal sweep circuit once each cycle, or once for every two revolutions of the engine. These pulses trigger a conventional sawtooth sweep voltage that is applied to the horizontal circuit of the cathode-ray tube. In actual operation the generator is mounted on the engine in such a position relative to the angular position of the tachometer drive shaft that the resulting pulses derived from the cylinder-cycle switch and pulse-forming circuits will trigger the horizontal sweep at exactly the instant the magneto breaker points open to fire, say, the number one cylinder if the cylinder-cycle switch is set to that cylinder. In a like manner, setting the cylinder-cycle switch to any other cylinder will shift the position of the pulse in one direction or the other by the amount necessary to cause initiation of the sweep to occur just as the breaker points open to fire that cylinder.

Having achieved the ability to initiate the sweep just as the desired ignition pattern is beginning to form, the sweep circuit has two adjustments such that instead of causing the electron spot merely to move across the tube face in two revolutions of the engine it will also move much more rapidly. Thus instead of seeing the ignition patterns for all the cylinders one after another, only the pattern of the cylinder being examined will be visible; but now the pattern will be greatly expanded horizontally (and may, indeed, be made to occupy the entire width of the tube face) thus facilitating analysis. The fast sweep is used mostly for ignition analysis where it is desired to expand the patterns considerably, while the slow sweep is used mainly for vibration analysis where it is more desirable to view the pattern for the entire cycle of cylinder events as one pattern rather than to have it broken up into a number of expanded sections. The slow

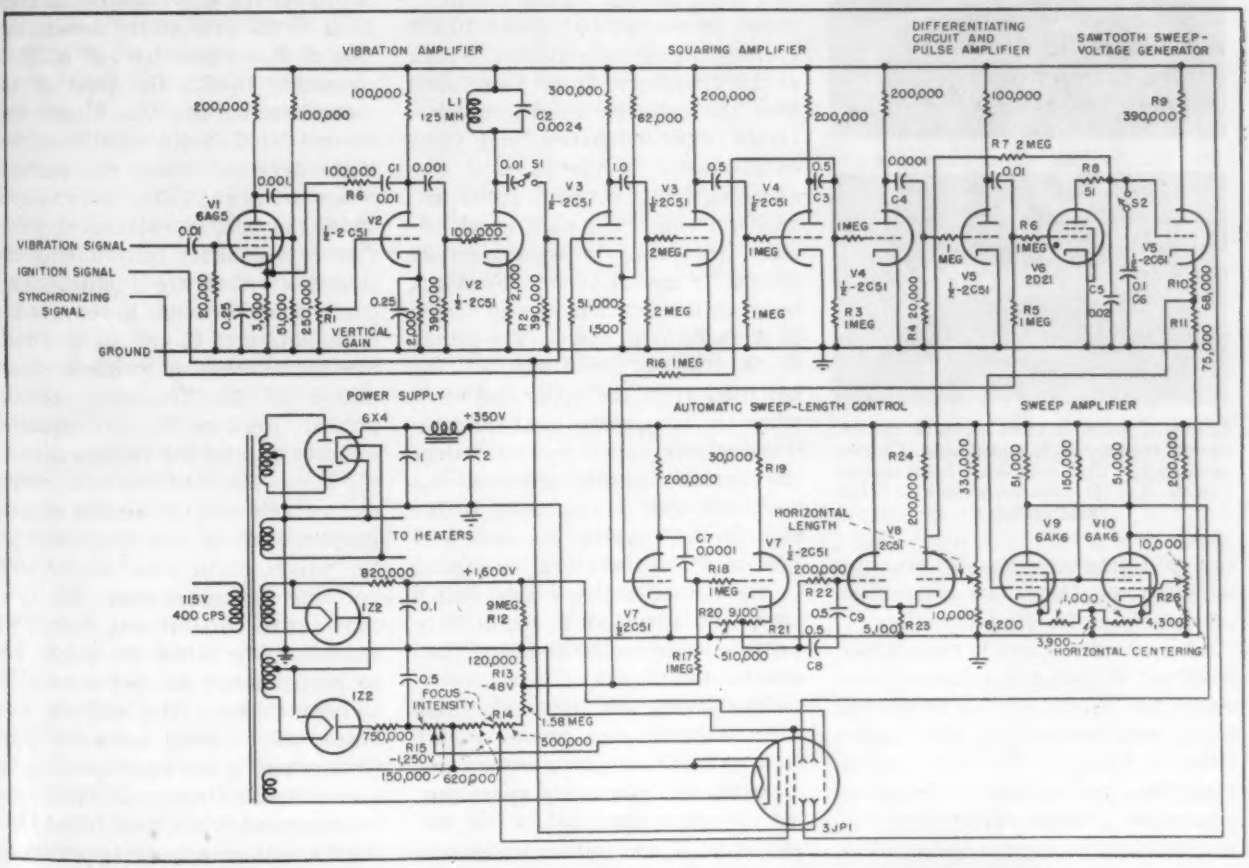

FIG. 3—Diagram of engine analyzer circuits. Value of capacitor C_5 is varied for different engines

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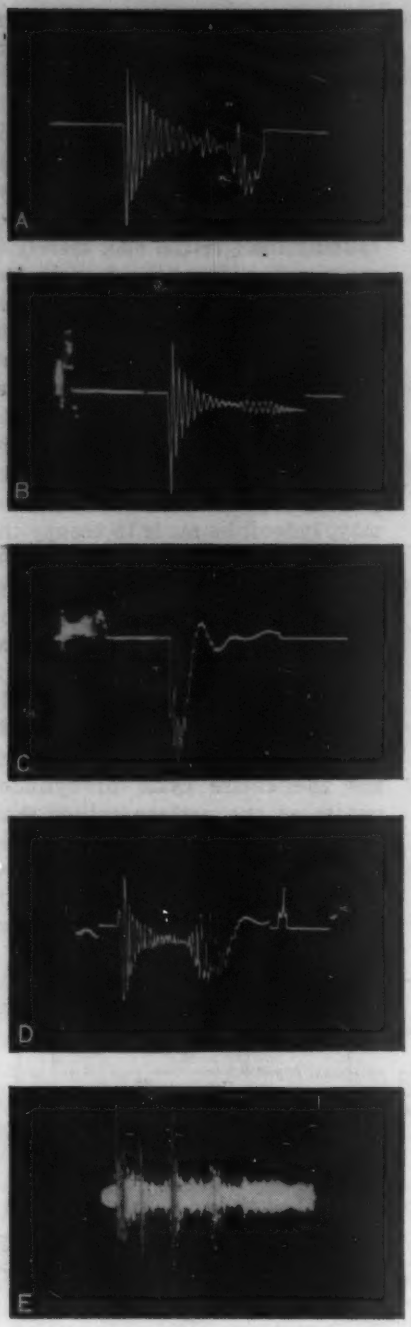

FIG. 4—Typical ignition patterns for (A) normal conditions, (B) fouled plug, (C) open secondary, (D) magneto breaker-point bounce, and (E) vibration pattern of a normal cylinder

sweep setting consequently provides a sweep requiring two revolutions of the engine for its completion.

If the sweep speed is maintained constant at either the fast or slow value the length of the horizontal trace will decrease as the engine speed increases. This effect results from the time between initiation of successive sweeps being inversely proportional to engine speed. For example, a 3-inch trace at 1,000 rpm would shrink to 1-inch length at 3,000 rpm. To remedy this condition an automatic sweep-length control is included. In effect this circuit measures the speed of the engine by measuring the frequency of the 3-phase generator voltage and adjusts the sweep speed accordingly. As the engine speed increases the sweep speed increases correspondingly to maintain the length of the patterns constant.

Electronic Circuits

A simplified diagram of the electronic apparatus used in the engine analyzer is shown in Fig. 3. All the electronic circuits with the exception of the cathode-ray tube, which is located remotely are contained in one box measuring approximately $8 \times 10 \times 9$ inches.

The vibration signal is amplified by tubes V_1 and V_2. The amplified signal appearing across R_2 is then applied directly to one of the vertical deflection plates of the cathode-ray tube, the other plate being grounded. The amplifier is entirely conventional except for the circuit consisting of inductance L_1 and capacitor C_2. This circuit is tuned to resonate at about 10,000 cycles, causing the amplifier to peak at this frequency. It has been found that the cylinder vibrations associated with detonation and valve events occur in the band of frequencies lying between 5,000 and 15,000 cycles. The gain is adjustable from zero to approximately 10,000 by means of R_1. Feedback between the first and second stages is provided by R_6 and C_1. The switch S_1 is provided to disconnect the amplifier from the upper end of R_2 when the analyzer is used for ignition analysis; this is necessary since the ignition signal entering the electronic unit is conducted to the cathode-ray tube by the same circuit used for the vibration signal. In the actual analyzer this switch takes the form of a small relay which is operated by the condition-selector switch.

Considering now the single-phase variable-angle sine wave coming from the cylinder-cycle switch and entering the electronic apparatus, the voltage is amplified in the first section of V_3 and subsequently converted into a square wave by the second section of V_3 and by the two sections of V_4 which follow. Capacitor C_4 and resistor R_4 serve to differentiate the square waves, producing positive and negative pulses. These pulses are amplified by the first section of V_5, resulting in positive pulses of approximately 50 microseconds in duration and 150 volts in magnitude, and also negative pulses that serve no useful purpose. The positive pulses are used to fire the thyratron V_6 and are applied to its control grid through R_5 and R_9. One end of R_5 is returned to R_{13} as shown. A potential of about 48 volts is developed across R_{13} and serves as the negative bias which maintains the thyratron in a nonconducting condition until a positive firing pulse arrives.

Sweep Length Control

The first section of V_7 is supplied with square waves from V_4, the frequency of these square waves being equal to the frequency of the 3-phase generator. The square waves are amplified by the first section of V_7 and then differentiated by C_7 and R_{17}. The resulting pulses, both positive and negative, are applied to the grid of the second section of V_7. Since one end of R_{17} is connected to R_{18}, the grid of the second section of V_7 is biased well beyond cutoff except when a positive pulse arrives. Since the positive pulses are about 150 volts in magnitude, the second section of V_7 is forced to conduct fully during the time the pulses are applied. This current flow through V_7 charges the combination of C_8 and R_{20} to a voltage the average of which is determined by the frequency of the pulses. Resistor R_{22} and capacitor C_9 serve to filter the voltage appearing across R_{20}, resulting in a smooth d-c voltage that is almost exactly proportional to the frequency of the pulses, or in other words, proportional to engine rpm. The time constant of this filter is about two seconds. The values R_{19} and R_{21} are so proportioned as to prevent the voltage between the cathode and heater of V_7 from exceeding 100 volts, which is the limit specified by the tube manufacturer. With this arrangement it has been found that the d-c voltage appearing across C_9 is virtually independent of varia-

tions in the tube characteristics.

The purpose of tube V_8 is to amplify the voltage appearing across C_5. By properly choosing the values of the components used with V_7 and V_8, it has been possible to make the voltage at the plate of the second section of V_8 almost exactly proportional to engine speed over a range of speeds from 1,000 to 3,000 rpm, and it is this voltage that controls the sweep length. This effect is accomplished as follows: the voltage at the plate of V_8 is applied through R_7 to capacitors C_3 and C_4. Assuming these capacitors to be uncharged at the start, they will charge through R_7 in the usual exponential manner. The voltage appearing across C_3 and C_4 is applied to the cathode-follower circuit of the second section of V_9. The output of this cathode follower is used to drive the sweep amplifier consisting of tubes V_9 and V_{10}, the plates of which are connected to the horizontal deflection plates of the cathode-ray tube. Two capacitors C_3 and C_4, provide the fast and slow sweep speeds mentioned above. When the fast sweep is desired only C_3 is used, whereas when the slow speed is needed, switch S_2 is closed, adding C_4. The velocity of the sweeps is inversely proportional to the value of capacitance in the circuit. Because only the linear initial portion of the exponential charging characteristic is required to effect the complete sweep from left to right, the sweep speed is nearly uniform and proportional to the voltage appearing at the plate of the second section of V_8, which in turn is proportional to engine speed. Thus the sweep speed is proportional to engine speed and, since the time for one sweep is inversely proportional to engine speed, it follows that the trace length will remain constant even though the speed of the power plant varies.

As the capacitors charge and the sweep reaches the end of its travel, the engine completes the two revolutions started at the time the sweep was initiated, and the thyratron V_6 is fired by the pulse discussed earlier. The thyratron discharges C_3 and C_4 through current-limiting resistor R_8 and the process of charging repeats; thus a linear sawtooth sweep voltage is generated. Since it is desirable to be able to adjust manually the actual length of the sweep that is to be maintained by the automatic control, resistor R_{23} is provided. By adjusting the potential of the grid of the second section of V_8 at some convenient engine speed, the plate voltage of that tube is set to give the desired length at that speed, after which the automatic action compensates for higher or lower speeds.

Horizontal centering of the entire trace is accomplished by adjusting R_{20}.

It should be noted that the components comprising the sawtooth generator, cathode follower and sweep amplifier were chosen so that: (1) the minimum voltage ever appearing on C_3 and C_4 at the end of the sweep would be sufficient to insure reliable firing of the thyratron when the pulse arrives; (2) the maximum voltage ever appearing on C_3 and C_4 would not cause excessive current to flow through the thyratron; (3) the maximum energy ever appearing on C_3 and C_4 would be low enough that it could be dissipated by V_6 and R_8 in a time that is very short compared to the shortest sweep time; (4) the sweep voltage applied to the cathode-ray tube would be linear under all conditions; (5) the maximum voltage between the cathodes and heaters of V_9, V_8 and V_{10} would never exceed 100 volts; and (6) the maximum ratings of all components would not be exceeded under any condition.

The power supply used in this apparatus is conventional.

The focus and intensity of the cathode-ray tube are adjusted by R_{14} and R_{15} respectively.

Typical Results

The results obtained by use of the engine analyzer can best be shown by means of photographs of the cathode-ray screen while the analyzer was in operation.

Figure 4 (A through E) shows ignition patterns as they appear under various engine conditions. Space does not permit a detailed discussion of each photograph; however it has been possible to explain nearly all the patterns in terms of the electrical parameters of the ignition system. These photographs apply to a high-tension system, and while the corresponding patterns for a low-tension system are somewhat different in form, they too can be analyzed and used in the identification of faults. While only photographs showing normal ignition, fouled plug, open secondary, and breaker-point bounce have been included, numerous other patterns are available showing such conditions as shorted secondary, large plug gap, small plug gap, shorted primary capacitor, no combustion, and magneto mistiming. Breaker-point bounce, (Fig. 4D) shows a pattern almost exactly like the one for normal ignition, except for the sharp pip near the end of the trace indicating that the points bounced open at that time after closing an instant earlier.

Figure 4E shows a typical normal cylinder vibration pattern. It will be noted that there are four distinct points at which the vibration rises to values considerably higher than the rest of the pattern. Counting from the left, these points represent (1) the closing of the exhaust valve; (2) the injection of the fuel; (3) closing of the intake valve; and (4) vibration due to combustion. When any of these cylinder events become abnormal, the particular portions of the pattern change greatly in magnitude. Thus when a cylinder detonates (knocks) the combustion portion of the pattern increases in height considerably. With a little practice, one can distinguish at a glance nearly any vibration abnormality.

Acknowledgment

The author wishes to acknowledge the helpful suggestions given him in the writing of this paper by J. W. Wheeler and R. W. Brown of the Engineering and Publicity departments, respectively, of the Sperry Gyroscope Co., and to thank Charles Plate of the Sperry Design department for his work in preparing the illustrations.

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Space-Charge Tetrode Amplifiers

Performance of developmental space-charge audio output tetrodes is compared with that of 6K6 pentodes, 6V6 beam pentodes, and 45 triodes in push-pull output stages of high-quality amplifiers. Developmental tubes not only outperform other types, but also require less costly components and simpler circuits

By NORMAN PICKERING
Pickering and Company, Inc.
Oceanside, N. Y.

IN THE AUGUST 1947 issue of ELECTRONICS W. S. Brian described a space-charge grid power output tube that he had developed. In cooperation with Brian, a number of tests were made in which the performance of these tubes in a high-quality amplifier was compared with that of some standard tubes. It is the purpose of this article to report the results of these tests.

An amplifier was constructed in which provision was made for changing the output tubes, everything else remaining the same. Four sets of output tubes were tested—the 6K6 as representative of a pentode, the 6V6 as a beam tetrode, the 45 as a triode, and the new space-charge tubes under discussion. The 6V6 and the 45 were used, rather than the 6L6 and 2A3, because their power capacity is of the same order as that of the space-charge tubes available.

The standard type tubes were quite well matched; the space-charge tubes were quite badly mismatched, one tube having about twice the power output of the other. This circumstance was accidental, having arisen from the fact that two tubes of the better type were not available among the experimental models constructed. Therefore, the results for the space-charge tubes, while significant, are by no means optimum.

The nominal rating of the space-charge tubes used was 2 watts per tube. Since these tubes are operated strictly as class-A amplifiers, the push-pull amplifier was rated at 4 watts. The 6V6 tubes are rated in the tube manuals at 14 watts under the conditions used in these tests, 6K6's at 9.8 watts, and the 45's at 12 watts. In these experiments, even when allowance was made for the losses in the output transformer, the pentodes and beam power tubes failed to deliver rated power.

Measurements were made on all four amplifiers of both harmonic and intermodulation distortion versus power output. The optimum load resistance was first determined experimentally and that value used for the measurements. In the case of the three standard tubes, the load resistance thus determined agreed very closely with the published values. The push-pull, space-charge-tube amplifier gave the greatest power at the lowest distortion with a plate-to-plate load of 20,000 ohms.

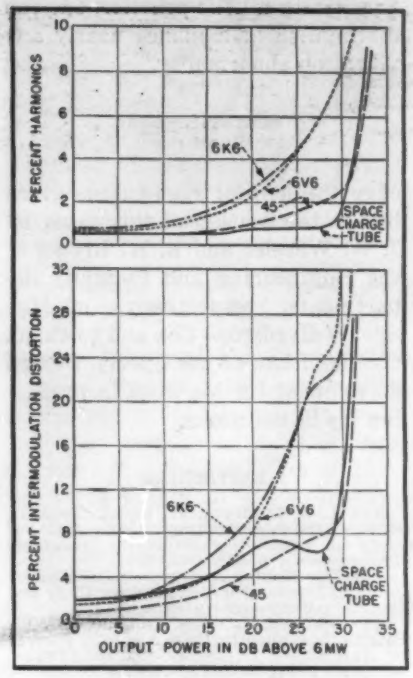
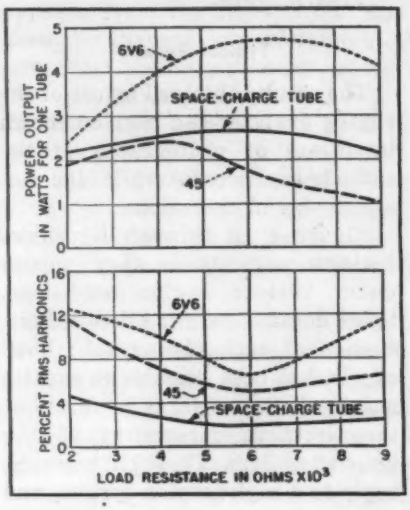
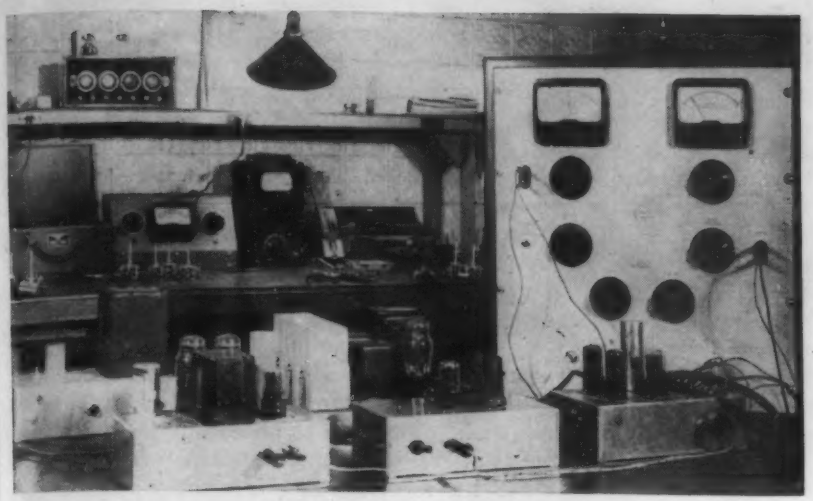


FIG. 1—Harmonic and intermodulation distortion versus output for resistive load

FIG. 2—Power output and harmonics show less variation for space-charge tubes





Three amplifiers undergoing comparison tests

Harmonic distortion was measured at 300 cycles by means of the high-pass filter method. The filter used to remove the fundamental had an attenuation of 60 db at 300 cycles, and less than 1 db at 600 cycles and above. The harmonic content was indicated on a vacuum-tube voltmeter reading rms volts. No attempt was made to analyze the harmonic content of the output waveform. Since the filter and vacuum-tube voltmeter were both flat to well above 20kc, it was assumed that all significant harmonics were included in the summation.

Intermodulation was measured on a Pickering Model 502 Intermodulation Distortion Meter. In this instrument, measurements are made at 100 and 7,000 cycles, with the low-frequency signal 12 db above the high-frequency signal. The percent intermodulation is specified as the degree of modulation of the 7-kc carrier after the low frequency has been filtered out.

It is felt by some engineers that harmonic distortion and intermodulation distortion measurements give essentially the same results, and therefore that there is no point in making both measurements. It is true that with a complete wave analysis and hours of laborious computation the intermodulation in an amplifier can be predicted. A simple harmonic distortion measurement, however, cannot indicate anything about the intermodulation, since the latter is dependent on the order as well as the magnitude of the harmonics.

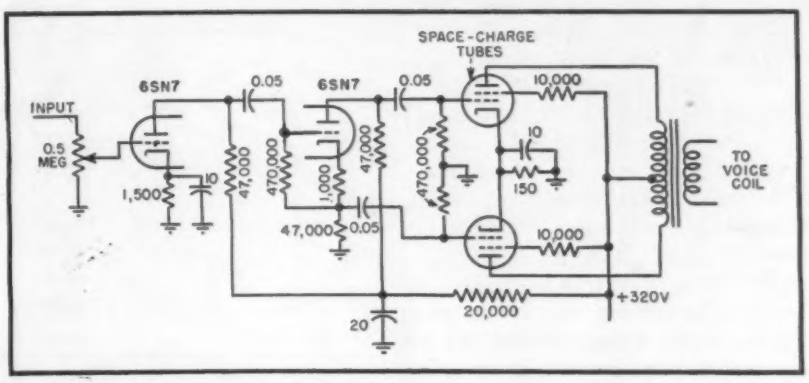
A word should be inserted here about the permissible limits of harmonic and intermodulation distortion for good quality amplifiers. For many years 5 percent harmonic distortion has been accepted as the tolerable limit for good amplifiers. This limit was found to be far too lenient for even medium-quality equipment, especially that using beam-power or pentode tubes, since 5 percent harmonics from these tubes is much more objectionable than 5 percent harmonics from triodes. Instead, it seems more practical to define a fair-quality amplifier as one having 2 percent total harmonics and 10 percent intermodulation, and a good amplifier as having 2 percent harmonics and 5 percent intermodulation. Judged by these ratings, many commercial amplifiers look pretty feeble.

Figure 1 shows the curves for harmonic distortion and intermodulation distortion in the four types of tubes. The bumps in the curves for the space-charge tubes are caused by the mismatch of the two tubes. It must be emphasized that these curves were plotted with the tubes working into a resistive load, with each pair working into its own best load resistance. To evaluate the performance of the amplifier working into a reactive load, such as a loudspeaker or cutting head, more extensive tests were made.

Comparison of Tubes

Characteristics of the four types of tubes used in these tests are given in Table I. Several interesting conclusions emerge from this comparison. Dynamic plate resistance, transconductance, amplification factor and plate supply voltage are listed merely to describe the tube and its condition of operation. The design engineer will find greater interest in the fifth heading, which shows that the drain on the power supply is greatest with the space-charge tubes. However, since these tubes are strictly class-A amplifiers, there is no rise of plate current toward full power output, the quiescent plate current being the maximum plate current; in the three other types of amplifier there is a plate current rise of from 10 to 30 ma at full power output. This plate current variation necessitates a power supply having fairly good regulation. The supply to the space-charge tubes can have a fairly high impedance without appreciable detrimental effect upon performance.

The ultimate power output repre-



Simplicity and low cost are features of this high-quality space-charge tetrode amplifier

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sents the power that the load connected to the tubes must withstand in the event of accidental overload. Much more significant is the grid voltage required to obtain this power. Here the triodes compare badly, while the space-charge tubes are found to be even better than the pentodes and beam tubes, which are notably easy to drive.

The efficiency of an audio amplifier has been defined as the ratio of the power output with 5 percent harmonic content to the d-c power input.

The figures for power output at a given percentage of harmonic distortion are greatly at variance with the published literature on the standard tube types. These measurements were carefully made, and all recommended operating voltages adhered to very closely. It is felt that these conditions often prevail in practice regardless of the results obtainable in the tube laboratory.

At low values of harmonic distortion, the space-charge tubes are about twice as good as the triodes. The others are not even close to this standard of performance. However, from the intermodulation standpoint, the triodes are about 1 db better which indicates that the small amount of harmonic distortion in the space-charge tubes is of a higher order.

The figures for practical efficiency are rather remarkable, because they show the triode to be the most efficient.

The effective amplification highlights the weakness of the triodes, and also brings out the astonishing fact that the 6V6 with an amplification factor of 230 provides a useful gain of only 13.3. The space-charge tube, on the other hand, realizes a net gain of 16.6 with an amplification factor of 20. This is another advantage of low plate resistance.

The effective generator impedance, or damping factor, is a most important characteristic of a power amplifier that is used to drive a loudspeaker. This impedance should be low because the electromagnetic damping of a loudspeaker depends on circulating currents through the generator impedance. Furthermore, it is desirable, when working into a reactive load, to develop as nearly as possible a constant voltage. To satisfy this requirement would demand a zero-impedance output stage, which is ordinarily impossible. In practice, however, a generator impedance equal to the nominal load resistance is satisfactory; a generator impedance less than this value is even better. The effective output impedance was measured by first observing the open-circuit voltage and then loading the amplifier until the voltage was reduced 6 db, or 50 percent. At this point the load resistance and generator impedance are equal.

Table I shows that the effective generator impedance is five times the load resistance for the beam-power tube, four times for the pentode, only 80 percent for the triode, and 50 percent for the space-charge tubes. This property of the space-charge tube makes the bass response cleaner and free from hangover. It also prevents the voltage rise at high frequencies which is characteristic of the pentodes and beam-power tubes. It is primarily to obtain this damping effect that negative feedback is used with the latter types of tubes. To obtain the same damping effect with the 6V6 tubes which is inherent in the space-charge tubes 20 db of feedback is required.

Practical Amplifiers

Three complete amplifiers were constructed using push-pull 6V6's, 45's and space-charge tubes. Every effort was made to make each of the amplifiers of as high quality as possible. A great deal of difficulty was experienced with the driver stage for the triode tubes. It was found impossible with ordinary voltage-amplifier tubes to drive the grids of the output tubes with a resistance-coupled phase inverter or even a resistance-coupled amplifier stage without having the driver overload before the output tubes did. Therefore, transformer coupling was used, adding considerably to the cost of this amplifier. Experience indicates that overloading of the driver is a common problem in triode amplifiers.

The output-transformer primary inductance is in shunt with the load, and at low frequencies increases the loading on the amplifier tubes. This effect reduces the amount of useful power applied to the load, and in the case of the triode and beam-power tubes, substantially increases the distortion at low frequencies. Figure 2 shows the manner in which power output and distortion varies with load for the three types of tube. The ability of the space-charge tube to ignore variations in

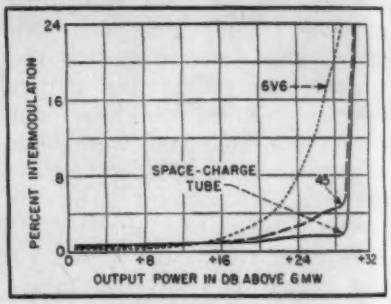

FIG. 4—Intermodulation distortion as a function of power output is shown for three amplifiers

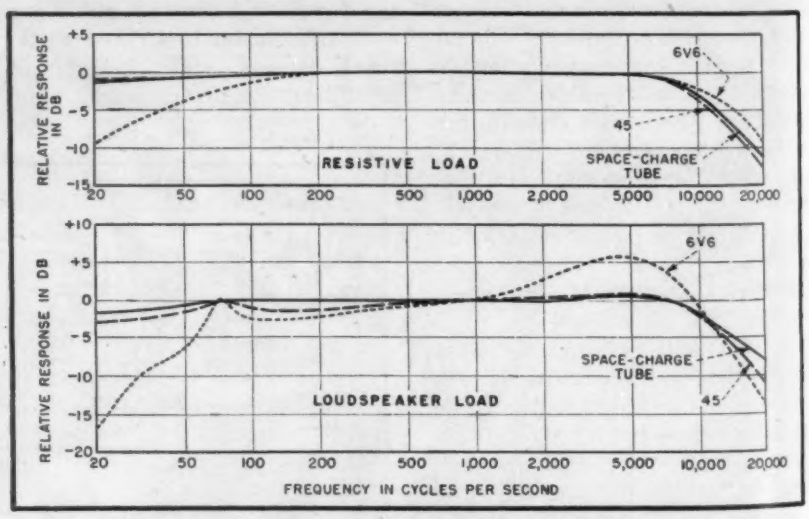

FIG. 3—These frequency response curves were obtained from amplifiers using three types of tubes with both resistive and loudspeaker loads

load impedance is an important advantage. No more primary inductance in the output transformer is required for the space-charge tubes than for the triodes. A value of 10 henries is quite adequate for response within 1 db to 30 cycles. The beam-power tubes, on the other hand, require at least twice the inductance for equivalent bass response into a resistive load. For the same core structure, the transformer for the space-charge tubes will have the same number of primary turns and half the number of secondary turns as the triode transformer. This construction will reduce the cost of labor and materials, at the same time reducing the I^2R losses in the secondary winding and reducing the leakage reactance. This is a case where something is had for nothing.

The measured frequency response of the three amplifiers with both resistive and loudspeaker loads is shown in Fig. 3. The same output transformer was used on all three amplifiers, the secondary taps being changed to match the various load impedances. The primary inductance was 15 henries, which is more than necessary for the space-charge and triode amplifiers, and less than desirable for the beam power tubes. The effect of a low generator impedance when working into a loudspeaker load can be seen clearly.

In order to conduct listening tests with any degree of similarity between pairs of amplifiers, it was necessary to equalize the 6V6 amplifier so that it had about the same high frequency response as the other amplifiers. This was accomplished by connecting a 10,000-ohm resistor in series with a 0.05-μf capacitor from plate to plate of the 6V6 tubes. Little could be done about the low-frequency peak.

Another effect which showed up when switching from one amplifier to another was an apparent change in relative volume at low and high levels. When all amplifiers were adjusted for the same loudness at low levels, the space-charge amplifier sounded louder at high levels. Conversely, when adjusted on loud passages to the same loudness, the 6V6 amplifier was loudest at low levels. Measurements showed that the 6V6 amplifier departs from linearity almost 10 db below its peak voltage input. The space-charge tubes, on the other hand, are linear to within about 3 db of maximum input. The triodes depart from linearity somewhere between these levels. Naturally, this effect is closely related to distortion, because a nonlinear device is by definition both a harmonic generator and modulator.

Table I—Comparison of Tube Characteristics

Tube Type	6V6	6K6	Space Charge	45
Dynamic plate resistance R_p at quiescent operating point, ohms	65,000	75,000	4,000	1,700
Transconductance g_m at quiescent operating point, micromhos	3,600	2,100	5,000	2,050
Amplification factor μ ($R_p \times g_m$)	230	150	20	3.5
Plate supply voltage E_b	285	285	325	325
Total cathode current I_c, milliamperes	74	62	110	92
Total d-c power supplied to tubes, ($E_b \times I_c$) watts	21.2	17.7	35.7	29.8
Optimum load resistance R_L, ohms	8,000	12,000	20,000	5,000
Ultimate power output, watts	12.5	8.5	11.0	13.5
Peak grid-to-grid volts for ultimate power output	42	54	36	150
Power output at 5 percent harmonics, watts	2.4	2.4	10.7	12.0
Power output at 2 percent harmonics, watts	0.32	0.50	6.6	3.8
Power output at 10 percent intermodulation distortion, watts	0.76	0.61	4.8	6.0
Efficiency as a-f amplifier, percent	11.3	13.5	30.0	40.0
Gain—actual amplification, $\mu R_L/(R_L + R_p)$	13.3	11.1	16.6	2.6
Effective generator impedance, ohms, 500 ohms load	2,500	2,000	250	400

It is interesting to examine the intermodulation distortion of the three amplifiers with loudspeaker load, shown in Fig. 4. Observe that the space-charge tubes, because of their ability to work well into a load of variable impedance, show the lowest intermodulation percentages. The triodes are very nearly as good, but the 6V6 tubes are considerably worse.

Comparison of Amplifier Costs

To perform as well as the triodes and the space-charge tubes, the 6V6's require at least 20 db of feedback. For this feedback, an additional stage of amplification is required and careful attention must be paid to phase shift within the feedback loop. In addition to these expensive modifications, the circuit requires a costly output transformer having a frequency range far in excess of the useful passband, in order to prevent oscillation. There is the additional point that the same amount of feedback applied to an amplifier using space-charge tubes will improve it by the same factor.

The expense of the driver stage makes it difficult to construct a low-cost amplifier using triodes, even though the output transformer is less expensive than that for the beam power tubes.

Since inverse feedback is hardly necessary with the space-charge tubes, a high-quality amplifier can be built that is capable of supplying full power output over a wide frequency range from a grid input signal of 30 millivolts. Such an amplifier would need only three stages including the output tubes. Savings in the power supply result from reduced heater-winding capacity on the power transformer, and a reduction in the amount of plate-supply decoupling necessary. A suitable output transformer could be made for a retail price of about four dollars. The retail cost of the parts required to build a completely satisfactory amplifier, flat within 1 db from 30 to 15,000 cycles, with intermodulation of less than 5 percent at 10 watts, is less than twenty-five dollars, including tubes and power supply. The only drawback at present is the fact that the tubes are not yet available. It is hoped that they will be in production before too long.

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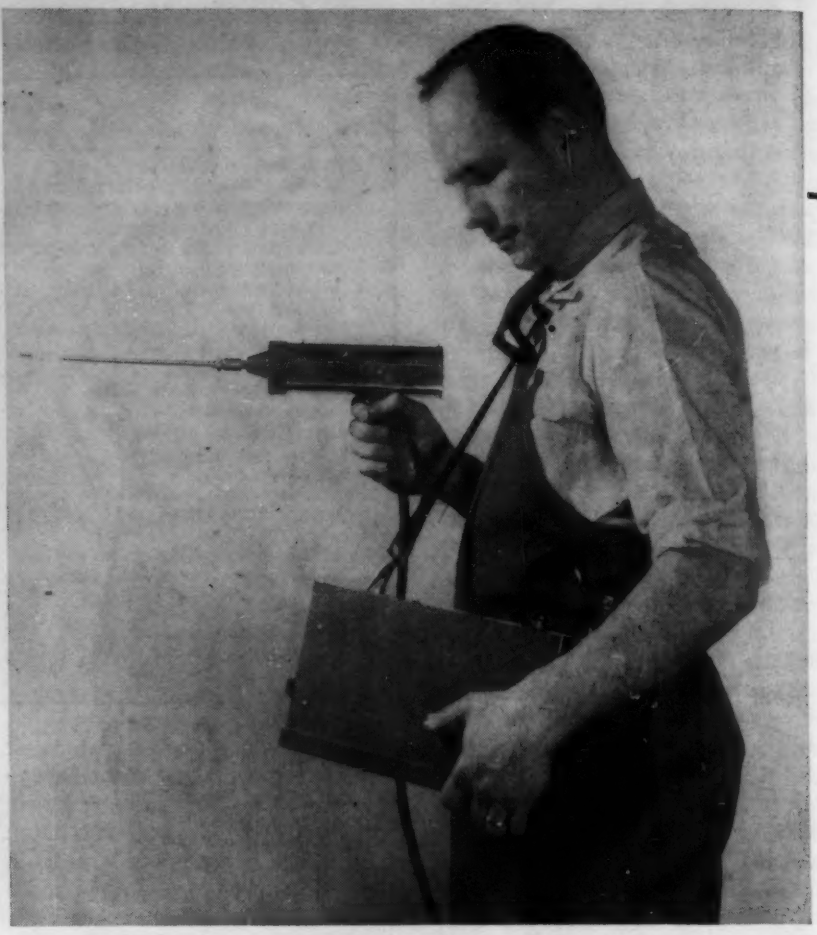
Sensing element of the leak detector, a diode of unusual design employing positive ion rather than negative electron emission and operating in air



Leak detector with supersensitive nose, one example of an instrument utilizing a long-neglected principle to simulate another of man's senses

Electronics Simulates Sense of Smell

Platinum, heated to incandescence, freely emits positive ions in air and does not readily oxidize. Emission is increased when halogen vapor compounds, of which Freon and carbon tetrachloride are good examples, are present. Use is made of this principle to detect leaks

THE SCIENCE of electronics has provided instruments which, in a practical way and to a remarkable degree, give responses similar to the human senses. Examples of this are the microphone, which performs like the ear; the loudspeaker and its similarity to the voice; the phototube and the eye, and a number of instruments equivalent to the sense of touch.

The sense of smell, as the human nose operates in air, has to date not been well duplicated, although for certain specialized cases very sensitive detectors[1] have been developed. The device to be described is thermionic in its nature and is sensitive to a large variety of halogen compound vapors and air-suspended particles. It thus extends man's ability to simulate the sense of smell.

Engineers working with electron tubes understand negative electron emission. On the other hand, the emission of positive ions from a red-hot metal is not as well known, and little use has been made of this phenomenon.

Unlike electrons, which are simply basic units of negative electricity, ions are positively charged particles of some specific substance.

By W. C. WHITE
and
J. J. HICKEY

Research Laboratory
General Electric Company
Schenectady, N. Y.

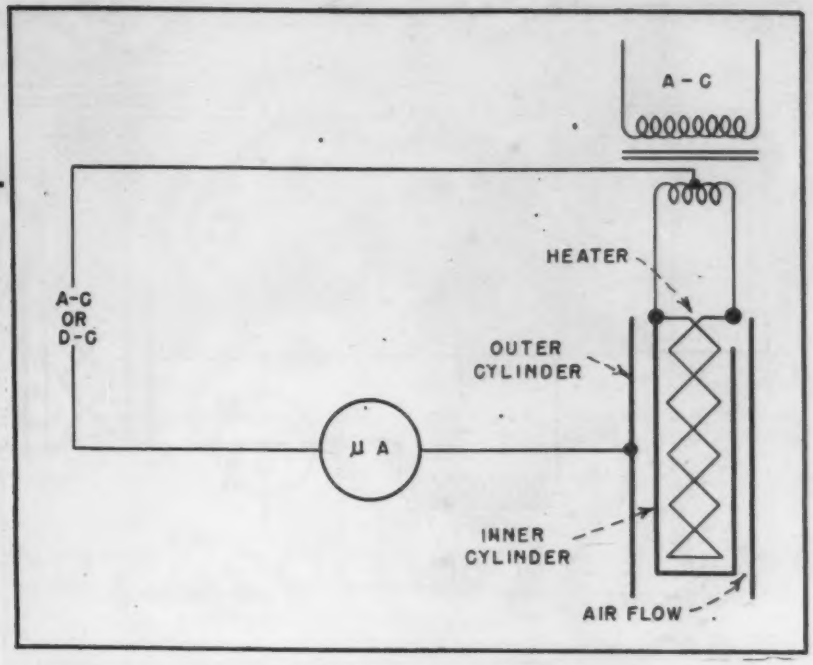


FIG. 1—Basic circuit of the new device

In general, emission of ions means a loss of material from the cathode emitting them. One unique feature of ion emission, however, is that it can be made to occur readily in the air.

Owing to the fact that platinum can be operated at a red heat with little oxidation and loss from evaporation, this metal is very useful as an ion-emitting source. The volume of ion emission from platinum varies greatly, depending upon temperature, area and nature of the surface, and purity of the metal. Ion emission current drops slowly with time, eventually reaching, however, a small but finite equilibrium value.

Twenty-five to fifty years ago, some scientific work was done on this phenomenon[a], but with the coming of electron tubes in their evacuated, sealed envelopes conduction in air was neglected for the newer, more intriguing, and simpler phenomenon of electron emission in a high vacuum. When early reports on conduction in air are studied it is soon realized that the experimental results obtained were very conflicting and the theories contradictory. In part this was due to the fact that electrical conduction through air is more complicated than in a high vacuum. There was also a less developed experimental technique available to early workers.

Operating Principle

It has been found by C. W. Rice that the steady emission of ions in air is increased to a marked extent when certain vapors strike the electrode surfaces. In the presence of even a small amount of a halogen compound vapor there is a marked increase in ion current. There is also a marked increase in current when suspended particles, such as smoke, containing a halogen compound contact the electrode surface.

Thus the essential elements of a halogen compound vapor detector, shown in Fig. 1, are:

(1) A two-element sensing structure, one suitable arrangement being in the form of concentric cylinders. The vapor to be detected is passed between these two closely spaced cylinders. The inner cylinder or cathode is kept red hot by an internal platinum-wire heater and the outer cylinder or anode is operated at a negative potential.

(2) A means of forcing air containing the vapor to be detected between the cylinders at a constant low velocity.

(3) Low-voltage a-c for the heater and another supply delivering a few hundred microamperes at somewhere between 50 and 500 volts a-c or d-c for use as the inter-electrode potential.

(4) Sufficient amplification to make a small increase in d-c current due to ion emission variation readily detectable.

General Characteristics

One of the characteristics of the device under operating conditions is the small amount of current that flows even in the presence of pure dry air. This current is usually of the order of 1 to 10 microamperes. In the presence of an air-diluted vapor of a chemical element or compound to which the device is sensitive this current will increase several fold.

Sensitivity to a halogen compound vapor varies with the velocity of air flow between the two cylinders. With an air flow of the order of one inch per second or less there is an extreme sensitivity to some vapors of about one part in a million. With an air flow of more than one foot per second the sensitivity and response are reduced to a point where there is little response.

The device is very sensitive to carbon tetrachloride, chloroform and Freon (dichlorodifluoromethane). At room temperature it does not respond to Pyranol (chlorinated phenol) but, if the Pyranol is heated to 60 C or more the vapor

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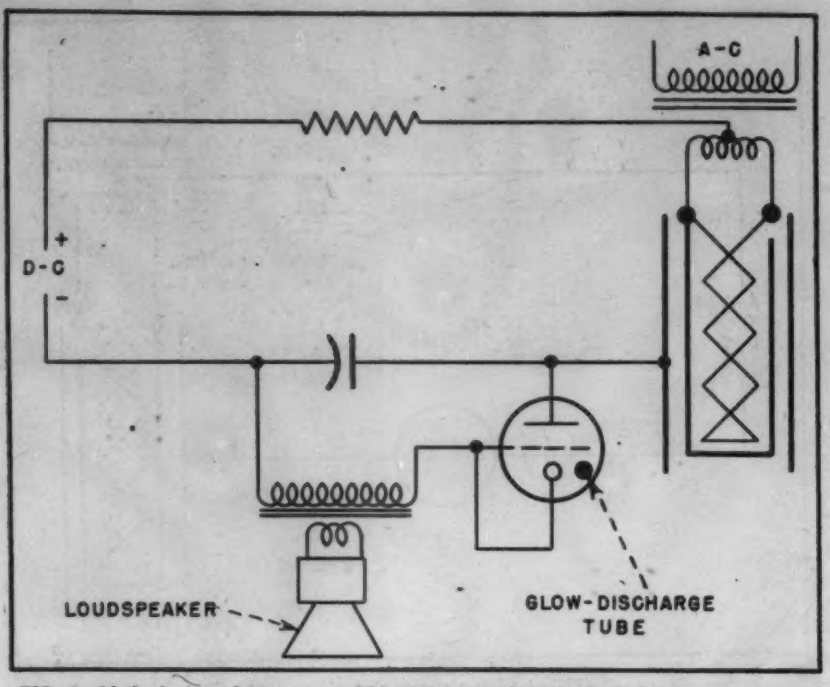


FIG. 2—Method of producing an audible response when the leak detector encounters halogen vapor compounds, or solid particles containing them, in the air

pressure becomes sufficiently high to give a response. It also responds to solid particles of the iodides, chlorides, bromides and fluorides. Therefore, it detects smoke from burning materials containing such compounds.

The detector is suitable in its present form for exposure to vapors, provided this exposure is limited to a relatively short time. If the sensing element is exposed to a halogen vapor for too long a time, or to a too highly concentrated vapor, it may lose its sensitivity. Long operation at full temperature in a current of pure air and with voltage between electrodes will restore its sensitivity if the contamination has not been too great. If the contamination has been too great it may be necessary to clean or replace the electrodes. The ease of contamination varies greatly from one compound to another. For instance, carbon tetrachloride contaminates the electrodes more easily than Freon.

If the sensing element has been hot for some time in the absence of an interelectrode voltage a heavy transient current flows when voltage is applied. The time taken to return to normal is dependent upon the time the element has been hot. A similar transient rush of ion current occurs if the interelectrode voltage is interrupted momentarily and then reapplied.

The device is quite sensitive to variations in air flow. If the air flow is too rapid then the vapor apparently has only limited opportunity to strike the hot cathode and dissociate. The sensitivity of the device therefore decreases as the air flow is increased. Part of the decreased sensitivity is also due to the additional cooling of the cathode with the increased air flow. On the other hand, if the air flow is at too low a rate the device will be extremely responsive to vapors to which it is sensitive but considerable time will elapse before the current returns to its normal no-vapor condition even after the inlet is again given a supply of pure air.

The response of the sensing element increases markedly with temperature over a narrow range. Below approximately 850 C, the emission current is too small to be easily utilized, and over approximately 950 C it becomes unstable and random fluctuations will hide any signal.

It is necessary to keep the space between the electrodes free from dust, cotton lint, or other particles that may be sucked in by the air flow. Such particles would short-circuit the electrodes and give false indications. It is usually desirable to filter the incoming air.

Indicating Methods

There are several ways by which the increase of current due to exposure to a vapor may be indicated. The simplest is by means of a microammeter or a galvanometer. Another method is to utilize the change in voltage across a high resistance to operate an amplifier which in turn operates a relay.

A third method is to add a relaxation-type of circuit incorporating a capacitor and glow-discharge tube, with a loudspeaker as an indicating element, as shown in Fig. 2. The current through the sensing element builds up a charge in the capacitor. When the voltage is sufficiently high the glow-discharge tube operates and the pulse of current resulting from the discharge of the capacitor produces a click in the loudspeaker. The repetition rate of the clicks is an indication of the amount of current passing.

With any circuit used, it is desirable to include a protective resistor to prevent injury to the sensing element and indicating device resulting from an overdose of vapor or a short circuit between electrodes. This may be of the order of 100,000 ohms.

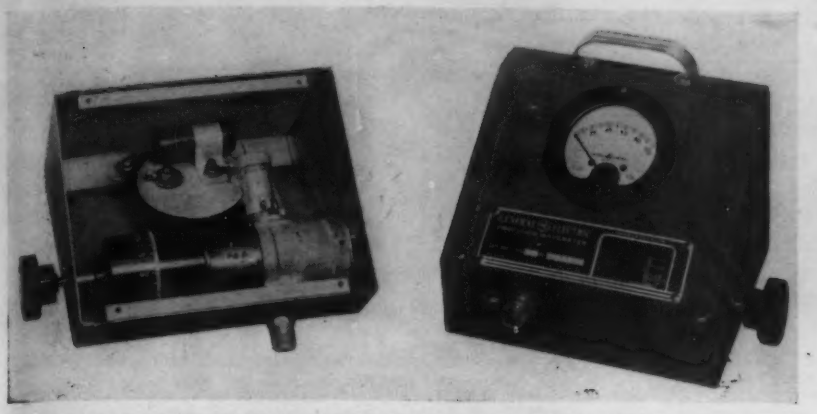
Use as a Leak Detector

The device is very convenient for detecting leaks in pressure systems of tanks, pipes, valves and flanges. In the case of a refrigerating system utilizing one of the Freon compounds under pressure, the operation consists of moving the intake nozzle of the unit near spots where a leak is suspected. For other closed systems a little Freon or other suitable halogen compound vapor is introduced as a tracer gas and air pressure is applied.

It is believed that this device will find wide application in industry due to the many products which must be made free from leakage before being used. Many other uses of the principle are anticipated.

References

(1) T. T. Woodson, Industrial Mercury-Vapor Detector, *Industrial Medicine*, p 22, April 1941.
(2) O. W. E. Richardson, "Emission of Electricity from Hot Bodies," Longmans, Green & Co.



Postwar re-entrant line short-circuit type of wavemeter for use in the frequency range from 8 to 12 cm, as described below

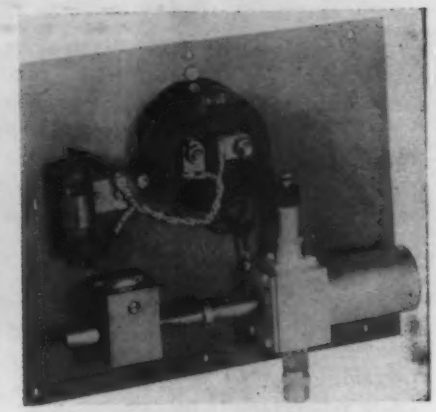


FIG. 1—A 5 to 30-cm searching wavemeter with finger contact to inner conductor

Direct-Reading WAVEMETER DESIGN

Construction details of direct-reading wavemeters for the range from 2 to 75 cm (15,000 to 400 mc). Theory behind maintaining linearity of wavelength-change-to-conductor-displacement is given for cavity devices of finger-contact and re-entrant line short-circuit type

By G. E. FEIKER and H. R. MEAHL
General Electric Co., Schenectady, N. Y.

THE development of wavemeters for use in the centimeter-wavelength range was accelerated after 1939, before which Lecher wires were probably in greatest use. Development of resonant coaxial transmission line and resonant wave guide cavity types followed.

All forms of the Lecher wire wavemeter require that two or more observations of resonance be made and that the distance of motion of a short-circuiting bar or plunger between points of resonance be measured to get data from which the signal wavelength can be calculated. A 5- to 30-centimeter searching wavemeter was developed to replace the various forms of Lecher wire device in order to conserve space and man-hours.

The back-panel appearance of the direct-reading 5- to 30-cm searching wavemeter is shown in Fig. 1. The device will agree with a primary standard of wavelength of frequency within 0.1 cm and will repeat a reading made using a crystal-controlled signal source within 0.05 cm.

A cross-section of the resonant cavity of this wavemeter is shown in Fig. 2. A coaxial transmission line resonator operates in its quarter-wave mode. Finger contacts are used on the inner conductor, the length of which is adjustable by means of a rack and pinion. The visual indication of resonance is obtained by converting a small amount of microwave energy to direct current with either a thermocouple or a crystal rectifier and applying it to a d-c microammeter. An input of approximately 20 milliwatts is required for full-scale deflection with a thermocouple and approximately one milliwatt when a crystal rectifier is used.

In order to obtain better accuracy and precision in another equipment, the size and shape of the contacting fingers were chosen to cause a minimum departure from a linear characteristic over a range from 30 to 75 cm. In addition, the coupling loops were adjusted to give uniformly good sensitivity over the whole range together with a characteristic sufficiently linear to allow the direct reading scale to be guaranteed accurate to within 0.5 percent.

In order to increase the effective

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scale length, the wavelength dial is rotated nearly two revolutions. The slope of wavelength versus conductor displacement was adjusted so that one set of graduations could be used with two sets of color-coded numerals. The correct scale is indicated by a colored target near the upper left edge of the dial.

Shielding for Accuracy

Experience with the 5- to 30-cm wavemeter showed a need for shielding against extraneous fields. Any r-f voltage induced in the nominally d-c path between crystal and microammeter is rectified to give a deflection. A combination bypass capacitor and instrument connection, together with grounding the input coupling and tuning shaft to the case, provided adequate shielding in the vicinity of high r-f fields.

A design similar to that of the 5- to 30-cm wavemeter has been made for the 2- to 8-cm range with the scale direct reading to within 0.05 cm between 3 and 8 cm.

Precision Wavemeters

An early form of laboratory wavemeter built for the dual purpose of investigating the characteristics of quarter-wave resonators as wavemeters of high precision in the 8- to 12-cm wavelength band and of measuring the output spectra of magnetron oscillators is shown in Fig. 3. Since the existence of discrete narrow spectra was suspected, a vernier tuning control shown at the right was included. However, the main tuning control proved adequate and tests showed that the resolution obtainable with a coaxial resonator employing a silver-plated micrometer spindle as adjustable center conductor was sufficient for all but the most specialized measurements in the 8- to 12-cm range.

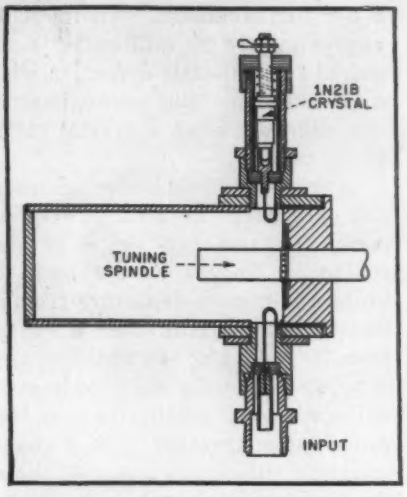

FIG. 2—Cross-section of 5 to 30-cm searching wavemeter

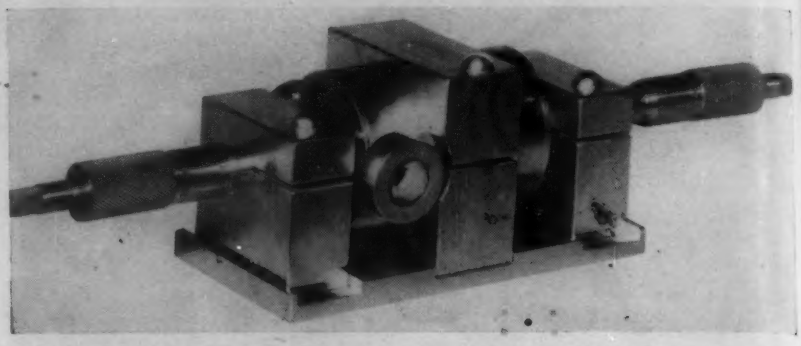

FIG. 3—A developmental 8 to 12-cm precision wavemeter with conductors for coarse and fine tuning

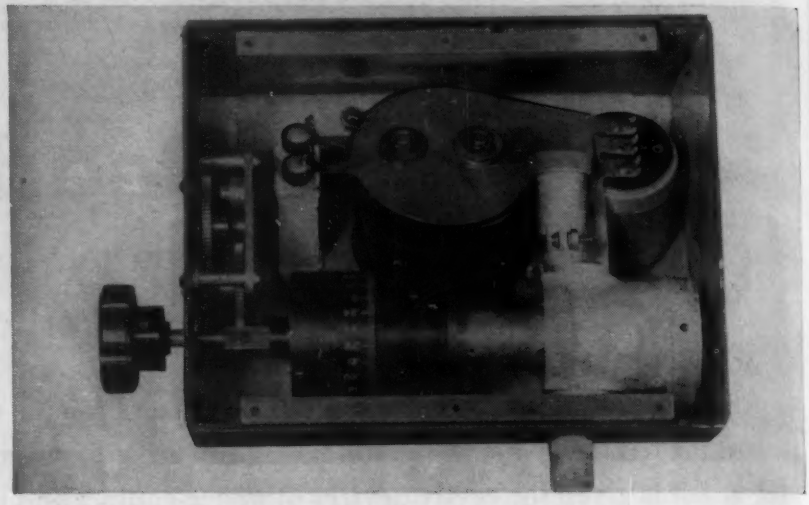

FIG 4—Field type precision wavemeter. Indicating meter is at upper center

Quantitative analysis and test of the performance of this laboratory wavemeter provided guidance in the design of wavemeters for field use. Improvements were made in the coupling loops, the contact between the micrometer-head mounting plate and the body of the wavemeter, the contact between the mounting plate and the micrometer spindle and in the body of the wavemeter itself. The measuring equipment had good sensitivity, full scale deflection for approximately 1 milliwatt input, and a wavelength versus displacement characteristic linear within 0.05 percent over the wavelength range of 8 to 12 cm. Positive low resistance contact is necessary both between the micrometer-head mounting plate and the body of the wavemeter as well as between the mounting plate and the micrometer spindle. It was found that the stiffness of a wavemeter body made of standard brass tubing was inadequate. Changes as great as 0.03 percent in tuning were caused by pressure on the clamp that held the body to the base.

In field wavemeters satisfactory contact between the micrometer-head mounting plate and the body of the wavemeter resulted from the combination of silver plating both parts and turning a lip approximately 0.005 inch high on the body of the wavemeter at its inner edge.

A satisfactory contact between the mounting plate and the micrometer spindle was obtained by making the micrometer spindle of sterling silver and the finger contacts of silver-plated phosphor bronze or beryllium copper. Motor driven

accelerated wear tests indicated that a year of trouble free performance could be expected from this combination. However, the re-entrant transmission line type of short-circuit which is described below is superior to the finger-type contact in having low manufacturing cost and more uniform and stable electrical characteristics.

Adequate stiffness in the wavemeter body has been obtained by means of a sturdy bronze casting, silver plated for high conductivity, shown in Fig. 4. This casting is securely bolted to the sloping panel to provide a sturdy mount for the input jack, output coupling loop, crystal rectifier unit, and tuning control.

Re-entrant Short Circuit

One of the most valuable features of the field type precision wavemeter is the re-entrant transmission line short circuit between inner and outer conductors of the resonator, shown in cross-section in Fig. 5. This accomplishes the same purpose as the finger contacts of earlier designs but without a mechanical contact between conductors of the main resonant cavity. The re-entrant portions of the cavity are proportioned so that the reactance at the input to the re-entrant line is zero at some intermediate wavelength in the band. At other wavelengths, the reactance is small in proportion to that of the main cavity. The rotating joint between micrometer spindle and head is at a low current point, so that the effect of this variable resistance contact on the wavemeter performance is negligible.

This design has resulted in an ideal working condition for the micrometer screw, since there is no load on the spindle. The construction provides a close approximation to the ultimate in uniformity and stability of both electrical and mechanical characteristics.

Further features of the field-type precision wavemeter are the direct-reading wavelength scale, accurate within 0.1 percent and resettable within 0.002 centimeter, and the combined shielding and bypassing that protect the wavemeter from strong radio-frequency fields and prevent responses to other than the impressed signal.

The appearance and construction of a postwar 8- to 12-cm precision wavemeter for general laboratory use is illustrated on the first page of this paper. Comparison with Fig. 4 will show that the gear-stop and sensitivity control of the field type have been omitted and that a less expensive bypass capacitor has been used across the microammeter, but that the primary structural and shielding features have been retained. The electrical characteristics of the two wavemeters are identical. Many of the benefits that accrue in designing for field use are not visible, but require a comparative study of the designs developed here and in England.[1] It is believed that the use of friction to hold the positions of the drum, the thimble, and the extension piece fixed relative to the spindle is indication that field use was considered secondary during the British development. The use of a 0.002-inch clearance for a distance of from $\frac{1}{8}$ to $\frac{3}{4}$ inch in the noncontacting plunger type also points in the same direction.

It is interesting to note the differences in electrical design, also. In the designs described herein the cavity beyond the end of the adjustable inner conductor has been chosen to be below cutoff for all operating wavelengths; whereas in the British design, the cavity is in the pass band for operating wavelengths. This difference apparently resulted from considering the direct-reading feature more important than width of tuning range while developing these designs.

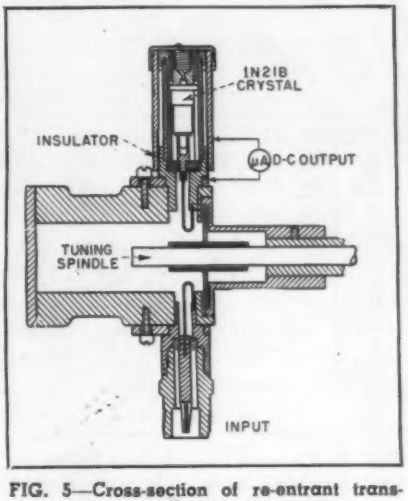

FIG. 5—Cross-section of re-entrant transmission line short circuit type

A 12- to 17-cm precision wavemeter operating on the same principles as those for the wavelength range 8- to 12-cm has the same quality of performance as detailed in Table I.

The precision type wavemeters are unusually well adapted for field service where extreme conditions of temperature, humidity, high-power radio-frequency fields in and out of the wavemeter range, vibration and shock are encountered. For example, the micrometer heads have been lubricated with a special oil which allows free movement at −60 C and yet does not evaporate at 50 C. Extensive use of these wavemeters for several years has shown that the wavelength calibration is maintained well within the 0.1 percent specification.

The devices have also been used as power indicators without modification, as receivers after connecting an audio amplifier across the crystal rectifier, and even as tunable band-pass filters after removing the crystal rectifier and connecting directly to the output loop.

Theory

The most important property of direct-reading wavemeters is the linearity of wavelength change to conductor displacement. The underlying theory of this property is presented below for those wavemeters employing finger contacts and those with a re-entrant transmission line short circuit.

It is an experimental fact that properly designed wavemeters having a resonator of the type shown in Fig. 6A have the property that a one centimeter increase in the length of the center conductor changes the fundamental resonant wavelength by four centimeters. It may at first seem obvious that this is the case, since the wavemeter is resonant in its quarterwave mode. Actually, however, the line is considerably shorter than a quarter wavelength because of the end-loading capacitance of the inner to outer conductor. This foreshortening may

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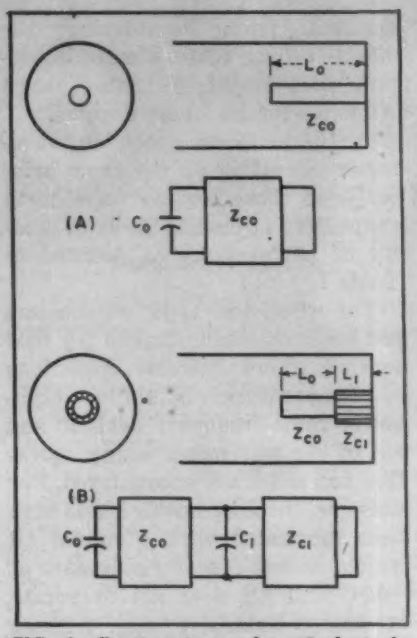

FIG. 6—Cross-section and equivalent circuit (A) of finger-contact type and (B) re-entrant type wavemeter

be as great as 18 percent of the quarter wavelength, and yet the rate of change of wavelength to conductor displacement is within 1 percent of the four-to-one relation.

It is difficult to make a good disc-type electrical contact of the kind needed in the resonator although such a contact was used in the early designs. The cylindrical type shown in Fig. 6B has been used in more recent designs requiring finger contacts because of its simpler construction. Resonators having a contact of this kind depart from the four-to-one relation and are not linear over the complete range of extension of the center conductor, but can be made direct reading within a fraction of one percent over a two-to-one wavelength range.

The resonator of Fig. 6A is a special case of that shown in Fig. 6B, the analysis of which is given below. The equivalent circuit for the latter consists of two cascaded sections of transmission line of characteristic impedances Z_{c1} and Z_{c0}. The former is short-circuited at its input end, and the latter is terminated in an equivalent end-loading capacitance C_0, representing the effect of the fringing field between the end of the center conductor and outer conductor. A capacitance C_1 is added to account for the step in the center conductor.[3]

The electrical length $\theta_0 = \beta L_0$ of the extensible portion of the center conductor can be related to the frequency and constants of the circuit. Referring to Fig. 6B, resonance will occur when the reactance of the parallel combination of line L_1 and fringing capacitance C_1 is the conjugate of the reactance of line L_0 terminated in the equivalent discontinuity capacitance C_0.

The input reactance of line L_1 is

$$X_{L1} = Z_{c1} \tan \theta_1$$

where Z_{c1} *and* θ_1 are the characteristic impedance and electrical length, respectively of line L_1.

Combining with the capacitive reactance $X_{c1} = 1/\omega C_1$,

$$X_1 = \frac{X_{L1}\, X_{c1}}{X_{c1} - X_{L1}} = \frac{(Z_{c1} \tan \theta_1)(1/\omega C_1)}{(1/\omega C_1) - Z_{c1} \tan \theta_1}$$

The input reactance of line L_0 terminated in the capacitance C_0 is

$$X_2 = -\frac{1/\omega C_0 - Z_{c0} \tan \theta_0}{1 + (1/\omega C_0 Z_{c0}) \tan \theta_0}$$

where Z_{c0} and θ_0 are the characteristic impedance and electrical length, respectively, of line L_0.

The condition for resonance, $X_1 = -X_2$, gives for θ_0 the relation

$$\tan\theta_0 = \frac{\frac{X_{c0}}{Z_{c0}} - \frac{Z_{c1}}{Z_{c0}} \tan \theta_1 \left(\frac{C_1}{C_0} + 1\right)}{1 - \frac{Z_{c1}}{Z_{c0}} \tan \theta_1 \left(\frac{Z_{c0}}{X_{c1}} - \frac{X_{c0}}{Z_{c0}}\right)} \quad (1)$$

The relation for the special case of Fig. 6A is obtained from Eq. 1 by setting $\theta_1 = 0$, in which case

$$\tan \theta_0 = \frac{X_0}{Z_{c0}} = \frac{1}{\omega C_0 Z_{c0}} = \frac{\lambda}{2\pi C_0 Z_{c0}} \quad (2)$$

where v is the velocity of propagation and λ the wavelength in cm.

If it were possible to eliminate end-loading so that $C_0 = 0$, the electrical length θ_0 would be 90 degrees. The magnitude of the effect of end-loading capacitance can be seen from Fig. 7, in which values of θ_0 are plotted for a wavemeter operating in the 8- to 12-cm range.

Of more importance is the expression for the rate of change of conductor displacement with wavelength, which can be found by differentiating the expression for the length L_0 of the extensible line.

$$L_0 = \theta_0/\beta = (1/2\pi)\ (\theta_0 \lambda)$$

$$\frac{dL_0}{d\lambda} = \frac{\theta_0}{2\pi} + \frac{\lambda}{2\pi}\frac{d\theta_0}{d\lambda} \quad (3)$$

The second term is obtained from the expression for tan θ_0,

$$\frac{d\theta_0}{d\lambda} = \frac{1}{D}\left[\frac{dN}{d\lambda} - \frac{N}{D}\frac{dD}{d\lambda}\right] \cos^2\theta_0 \quad (4)$$

where N is the numerator and D the denominator of Eq. 1.

For the case in Fig. 6A, the expression for the rate of change of wavelength to conductor displacement reduces to

$$\frac{dL_0}{d\lambda} = \frac{\theta_0 + 1/2 \sin 2\,\theta_0}{2\pi} \quad (5)$$

Let

$$\theta_0 = \frac{\pi}{2} - \epsilon$$

Then

$$\sin 2\,\theta_0 = \sin(\pi - 2\epsilon) \leqq 2\left(\epsilon - \frac{2}{3}\epsilon^3\right) \quad (6)$$

for $\epsilon < 0.5$ radian.

Therefore,

$$\frac{dL_0}{d\lambda} \leqq \frac{1}{4} - \frac{\epsilon^3}{3\pi} \quad (7)$$

The percent deviation from a

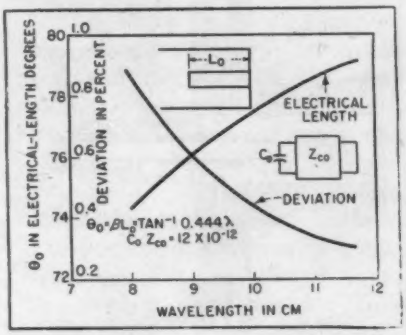

FIG. 7—Electrical length and deviation from the 4-to-1 slope in a finger-contact wavemeter

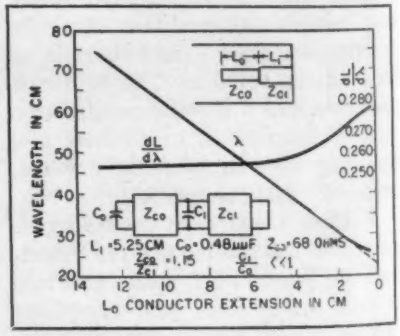

FIG. 8—Resonant wavelength versus conductor extension and slope for a re-entrant type wavemeter

4-to-1 slope has been calculated from Eq. 7 and plotted in Fig. 7 for the 8- to 12-cm range.

When the projecting type of contact is used, the rate of change is no longer four to one. The slope versus wavelength for a 30- to 75-cm wavemeter, and conductor length versus wavelength, have been plotted in Fig. 8. This wavemeter employed a contact line 5.25-cm long. The ratio of characteristic impedances Z_{c2}/Z_{c1} was 1.15. A reduction in the length of the contact line to 3.2 cm made the characteristic linear to within ± 0.5 percent over the range of 30 to 75 cm.

A cross section of a cavity type used in the 8- to 12-cm and 12- to 17-cm wavemeters is shown in Fig. 9. The main part of the cavity consists of two transmission lines, one having the variable length *AB* as inner and *MN* as outer conductor, the other having *JK* as inner and *LM* as outer conductor. The former line is terminated in a fringing capacitance from *A* to the outer conductor; the latter line is shorted by the plate *KL*.

The re-entrant portion of the cavity consists of the short-circuited line *HI*, *GF*, and the line *CD*, *FE*. The two parts of the cavity are connected by the choke line *BC*, *JI*. The center conductor rotates in its bearing at point *D*, this being the only point of mechanical contact between the outer shell and center conductor. The electrical quality of this contact is not important, since it is at a low current point relative to the current in plate *KL*.

An equivalent circuit for the cavity can be drawn, showing the interconnection of the five different transmission lines having characteristic impedances Z_{c1}, Z_{c2}, Z_{c3}, Z_{c4}, Z_{c5} and the discontinuity capacitances. The capacitance C_{12} represents the fringing capacitance from the end of the center conductor to the shell. Capacitances C_1, C_{13}, C_{23}, C_{45}, C_4, C_5 are those associated with the discontinuities at the junctions of the various transmission lines. These capacitances can be calculated from the dimensions.[2]

The following procedure is followed in calculating the wavemeter characteristic. The reactance appearing between terminals *S* and *T* due to the combination of networks 1, 3, 4, and 5, where each network consists of a transmission line and associated discontinuity capacitances, is calculated, ignoring losses. The electrical length of line of characteristic impedance Z_{c2} necessary to give the conjugate reactance across these two points is then determined. This calculation is carried out for several wavelengths over the band of operation to obtain the characteristic of extension *AB* versus wavelength. Matrix formulation simplifies the procedure of calculation.

Table I—Characteristics of 12- to 17-cm Wavemeter Calculated From Equivalent Circuit

λ	$\Delta\lambda/\Delta L_2$	I_{05}/I_{01}	P_1	P_2	P_3	P_4	Q
12		0.046	8.8	1.8	11.0	0.10	2250
13.25	3.540						
14.50	3.566	0.073	8.6	3.5	10.3	0.15	2260
15.75	3.550						
17.00	3.555	0.104	8.3	5.3	9.7	0.22	2280

$\Delta\lambda/\Delta L_2$ = slope of wavelength versus conductor displacement
I_{05}/I_{01} = ratio of current through rotating joint to maximum current
$P_{1,2,3,4}$ = power loss in various portions of cavity shown in Fig. 9
Q = Q—factor of overall resonator

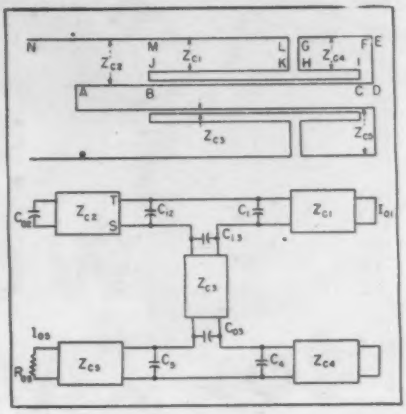

FIG. 9—Equivalent circuit for re-entrant type wavemeter

The equivalent circuit can also be used to calculate other properties of the resonator. The ratio of current I_{05} in the rotating joint at *D* to current I_{01} in the short-circuiting plate *KL* is of importance in the design. Distribution of loss in various parts of the cavity and the *Q* value of the resonator can also be calculated.

Table I gives values of slope of wavelength versus conductor displacement, $\Delta\lambda/\Delta L$, current ratio I_{05}/I_{01}, *Q*, and loss distribution for a 12- to 17-cm cavity.

In order to make the wavemeter direct reading, utilizing a standard micrometer screw thread, a slope of $\Delta\lambda/\Delta L = 3.543$ was required. The dimensions of the cavity were varied in initial trial calculations until the following series was obtained in which all dimensions are the same except the diameter of the center conductor of line L_1.

diameter (inches)	$\Delta\lambda/\Delta L$ (average)
0.320	3.58
0.330	3.55
0.340	3.53

The experimental value of average slope for the final design with a diameter of 0.330 inch was 3.536. The calculated value is in error by less than 1 percent. The experimental value is somewhat affected by the coupling loops, so that better agreement could hardly be expected.

It should be pointed out that the analysis is valid only for loose coupling, since over coupling can greatly change the calculated characteristics.

Acknowledgement

The authors take this opportunity to acknowledge P. E. Hosegood's contribution of the expanded scale feature to the precision wavemeters, F. J. Moles' development of the 5- to 30-cm and 2- to 8-cm searching wavemeters, and E. D. Cook's encouragement during the course of these developments.

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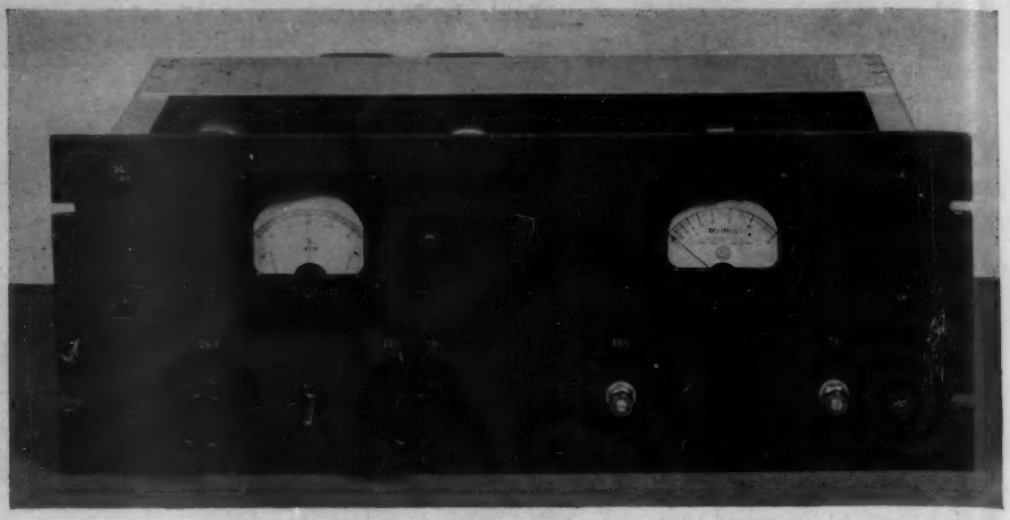

Electronic equipment used with the turntable tone generator

WOW METER for Turntable Testing

A toothed wheel rotating between two pickup coils connected for maximum output generates a tone. Output is fed through a peak clipper to a discriminator and rectifier. Instantaneous speed variation is shown directly on a calibrated meter

By G. L. SANSBURY and E. W. PAPPENFUS
Collins Radio Co., Cedar Rapids, Iowa

IN DISC RECORDING a common but annoying fault in reproduction is instantaneous speed variation of the turntable commonly called wow. Everyone is familiar with the discordant quavering of sustained piano or bell tones that are encountered in the reproduction of phonograph music. This is the direct result of turntable speed variation.

Wow can be detected by the listener when it occurs at a relatively low cyclic rate. One to three cycles per second in variation of frequency at 1,000 cycles seems to give the most noticeable wow at that frequency. The amount of wow that is detectable varies with frequency. A small amount is noticeable at high frequencies but only larger amounts at low; that is, a larger percentage of variation in frequency is tolerable when a low frequency is being reproduced.[1] In general, three-tenths of one percent instantaneous speed variation is the maximum that can be tolerated at any frequency without introducing noticeable frequency change in the reproduced tone.

Causes of Variation

There are a number of reasons for wow in turntables and these may be classified by the type of drive used.

In the rim-driven turntable eccentricity of the spindle, oval shape of the turntable, line frequency or between the spindle and the surface of the turntable, line frequency or voltage fluctuation, as well as variations in friction of any part of the driving mechanism during a portion of a revolution result in wow. In the spindle-driven turntable, out-of-round shaping of the turntable does not cause wow, but eccentricities in the driving gears or an eccentric spindle drive contribute to wow. Again, nonuniform bearing friction, variations in line frequency and voltage, and any inaccuracies in the drive mechanism

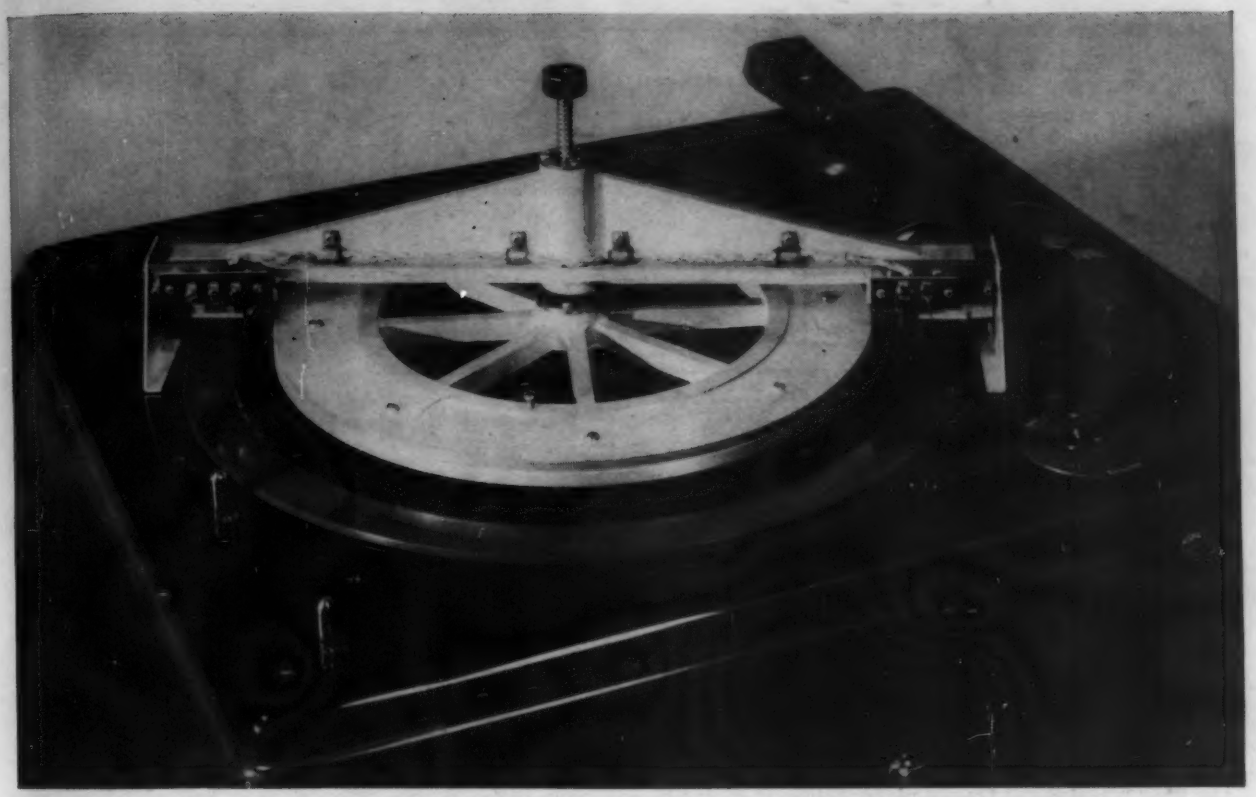

FIG. 1—Toothed-wheel tone generator centered on the turntable

tend to produce speed variation. Another factor that is somewhat difficult to control on the spindle-driven turntable is mechanical damping of the mechanism as the turntable is started. Frequently the turntable comes up to speed and overshoots slightly, then oscillates about the desired speed for a short time before it settles down to its constant-speed operation. In both types of turntable, variation in groove amplitude of the record causes a variation in torque that results in instantaneous speed variation if the drive motor does not have sufficient power or if the inertia of the turntable and its associated mechanism is not sufficient to carry through the momentary periods of greater torque requirements. This effect is similar to the problems involved in the design of a flywheel to maintain a required stability.

Since the requirements for constancy of speed in the phonograph turntable are so rigorous, it is important that a convenient means be devised for measuring instantaneous speed variation.

There are a number of methods by which the wow of a turntable might be measured.

Testing Methods

A method that comes to mind immediately is the familiar stroboscopic disc which is viewed in a 60-cycle light source. By observing the position of the dots or lines on the disc as the turntable is rotated, it is possible to check the average speed of the turntable. This method, however, is not practical for checking the instantaneous speed variation with an accuracy which is necessary in order to have a quantitative measure of turntable performance. It is true that the stroboscope disc does show up variations in turntable speed in the advancing rotation or reverse rotation of the virtual marks of the stroboscopic disc; but the motion is not easily measured because it ordinarily varies at a rate equal to that of turntable rotation. Since this method necessarily involves visual inspection, the observer errors are large.

Another method is to play a constant-tone record on the turntable using a conventional pickup, amplifier, and a frequency measuring system. There are a number of reasons why this is not entirely practical except as a rough approximation. This system must necessarily include any wow which is present in the original recording. It also includes wow contributed by any eccentricity of the record owing to off-center stamping of the blank or clearance in the center hole. These contributions to instantaneous frequency variation may add to or subtract from that present in the turntable being tested.

Another suggested means is to use a purely mechanical differentiating speedometer to measure instantaneous speed variation. This would be a rather difficult mechanical problem because the mechanism of the wow meter itself must be better at all times than the mechanism of the turntable. Building any measuring device to measure to within one-tenth of one percent is a major design problem. The differentiating speedometer must contribute no friction to the turntable itself and it must have low inertia so that it does not reflect into the turntable a

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speed variation which is not present normally.

The most practical means by which the instantaneous speed variation of a turntable can be measured seems to be the method suggested by H. E. Roys[2] in which a gear blank is cut with a suitable number of teeth so that by using magnetic pickup from the teeth a convenient tone is generated. This tone is fed into an amplifier and a frequency measuring circuit that operates a meter indicating the instantaneous speed variation. A gear is admirably suited for the generation of a constant tone because it is possible to machine the teeth accurately so that the errors in tooth spacing contribute very little to the error of measurement. The centering of the gear can be accurately maintained because the inside framework is constructed of metal as shown in Fig. 1.

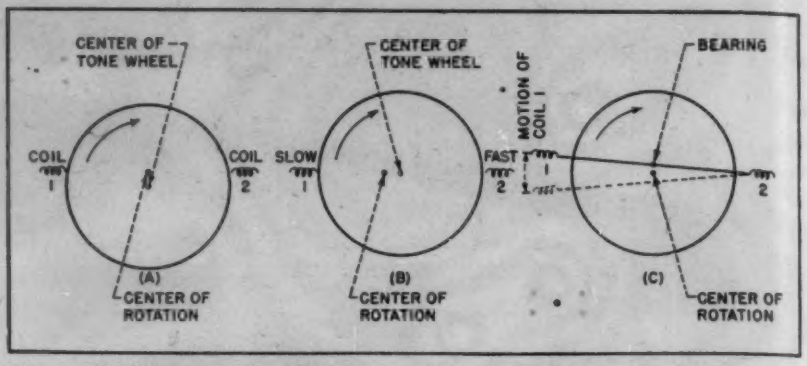

FIG. 2—Effect of wow on a single pickup coil (A and B) and upon a pair bearing on the center of the tone wheel (C)

Gear Dimensions

The gear wheel is cut from a plate of cold-rolled steel and mounted on an aluminum wheel having its center at the center of the turntable. The gear has a pitch diameter of 13.750 inches, and a diametral pitch of 56, giving an output of 1,004 cps at 78 rpm and 427 cps at 33⅓ rpm. A center-drilled shaft brings about alignment of the centers of the tone wheel and the turntable record-centering pin. Three screws are used for leveling the wheel on the turntable so that the pole piece of the pickup coil is in horizontal alignment with the teeth of the tone wheel.

At first thought it might seem that a single magnetic pickup from the tone wheel would be satisfactory. This, however, is not true. A single pickup coil would introduce a variation in tone generated by the gear itself owing to eccentricities that might be present. This effect is shown in Figs. 2A and 2B, in which the center of the tone wheel and the center of the turntable do not coincide. With the turntable and the tone wheel in the position 2A, the peripheral velocity at coil 1 is equal to the average speed of the turntable, while at 2B it is seen that because of the decreased radius the peripheral velocity adjacent to coil 1 is lower than the average. At coil 2 the velocity and hence the tone is higher than the average.

This effect suggests the spacing of two pickup coils at diametrically opposite points in the circumference of the tone wheel, so phased that a double voltage is obtained. Assuming a sinusoidal voltage from the coil (the output is actually very close to a sine wave), then the voltage from coil 1 is $E_{max} \sin(\omega t + \theta)$ and the voltage from coil 2 is $E_{max} \sin(\omega t - \theta)$ where θ is a variable which varies throughout the revolution. The two expressions for the voltage output from the pickup coil are seen to be phase modulated and the voltage from either of the coils would therefore result in an erroneous answer from any simple form of indicating circuit. If the two voltages are added together the sum is $2E_{max} \sin \omega t \cos \theta$. This operation demonstrates that the phase modulation drops out, leaving an amplitude term $\cos \theta$. Thus by using two coils an output voltage is obtained, the frequency of which is directly proportional to the speed of rotation of the turntable.

Originally, for the sake of convenience, the pickup coils were suspended on a bearing at the center of the tone wheel with one end of the pickup coil assembly prevented from rotating with the turntable by abutment with a fixed stop. In Fig. 2C is shown the result of having the pickup coil assembly eccentric with regard to the center of rotation of the turntable. If coil 2 is fixed in space, coil 1 oscillates between the solid and the dotted positions indicated in Fig. 2C, resulting in a variational output that is not balanced out even through the addition of the two coil output voltages.

The coils are made from number 30 wire, scramble wound, approximately 1,500 turns. A pole piece of cold-rolled steel projects through the pickup coil and is magnetically coupled to a permanent magnet of the type used in a moving coil meter and to the teeth of the gear. The exact magnetic structure of the pickup coil assembly is not important, since a satisfactory output is obtained with no difficulty.

Centering the Assembly

At the center of the assembly is a tapered centering shaft that is pressed down to engage with the center hole of the tone wheel so that the pickup coil assembly is properly positioned. Upon release of the centering shaft, the pickup coil assembly is supported at its extremities from the surface of the turntable cabinet. Adjusting screws are provided so that the pole pieces and pickup coils can be shifted slightly to obtain maximum voltage from the system. A maximum voltage is secured when the two coils are in corresponding positions with regard to gear teeth, giving an output voltage from each coil so phased that they combine additively.

Electronic Components

A wow meter developed by the writers for production testing of transcription turntables is built for mounting in a standard speech rack and is selfcontained except for the power supply. Provision for checking the turntables at both 33⅓ and 78 rpm is included. At the left of the instrument (illustrated) is a

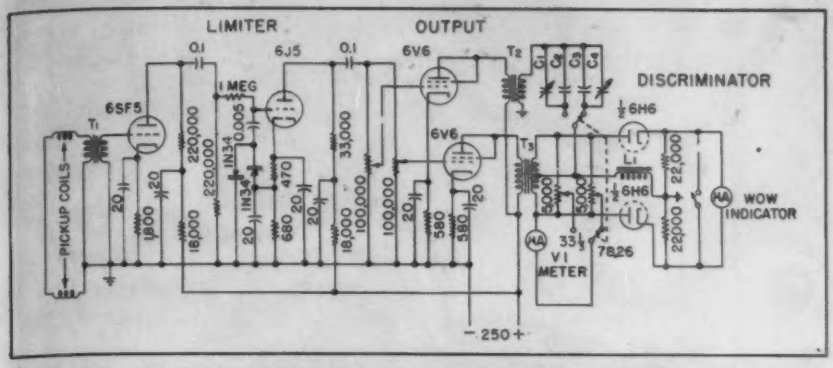

FIG. 3—Schematic circuit diagram of the wow meter. Shorting switch across the indicating meter prevents damage when turntable is started

meter directly calibrated in percent wow. On the right is a volume indicator for establishing the proper level for satisfactory operation. Below the volume indicator are two locking potentiometers for zeroing the volume indicator at both frequencies of operation. Below the wow indicating meter on the left is a meter shorting switch and the master gain control, as well as the 33⅓ and 78 rpm changeover switch.

In the schematic diagram of Fig. 3 may be seen a conventional voltage amplifier upon which no particular effort was expended to secure extended frequency response beyond 1,000 cycles and below 400 cycles. The input transformer matches the output of the pickup coils to the input grid with an impedance ratio of approximately 250 to 30,000 ohms. The first stage of the voltage amplifier uses a high-mu 6SF5 tube. The audio is then fed into a limiter circuit of the biased-diode type using germanium 1N34 diodes. This is in reality a peak clipper in which the diodes are biased with a voltage obtained from the cathode circuit of the second amplifier stage. A series grid resistor of 1 megohm provides a high impedance source so that effective peak clipping occurs whenever the peak a-c voltage exceeds the bias provided by the cathode circuit. The second amplifier stage consists of a 6J5 feeding the two output tubes. Since high frequency response is not required, it is satisfactory to feed the two 6V6 grid circuits in parallel. One 6V6 feeds the push-pull and the other the series portion of the discriminator circuit. A single 6H6 serves as a

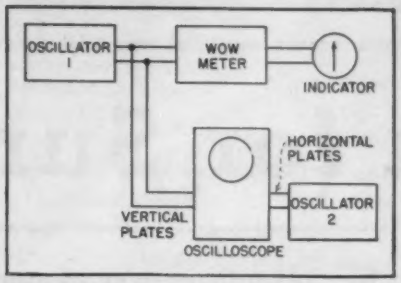

FIG. 4—Method of calibrating the meter by Lissajous figures

discriminator rectifier feeding a zero-center microammeter with an undamped movement. Two sets of capacitors, C_1 and C_2 for 33⅓ and C_3 and C_4 for 78 rpm, makes possible a more flexible wow meter for use with both turntable speeds. The variable portions of this tuned circuit C_1 and C_4 are high-capacitance variable ceramic capacitors that are convenient in this application. A volume indicator is connected across the output of one of the 6V6 tubes so that the proper voltage may be fed into the discriminator for satisfactory operation. This meter is switched with the variable capacitors used to tune the discriminator. Two 5,000-ohm potentiometers are used to adjust the volume indicator to zero at the level at which calibration was made. A shorting switch must be provided to protect the meter as the turntable comes up to speed. With a sensitive circuit such as must be used to detect wow of 0.1 percent, excessive deflection occurs with large frequency differences that are present before the turntable reaches its correct operating speed. Without the shorting switch severe pinning of the meter occurs during the starting of the turntable. The resonant circuit of the discriminator must use a high-Q audio coil at L_1 to secure adequate sensitivity. Since the inductance of L_1 varies with the a-c voltage present across it, it is necessary to hold the level into the discriminator at a value corresponding to that which was used during calibration.

Standards of Calibration

The block diagram in Fig. 4 shows a method by which the wow meter can be calibrated. Oscillator 1 is fed into the wow meter and the vertical plates of an oscilloscope, while oscillator 2 feeds the horizontal plates of the scope only. With the two oscillators at the same frequency, the usual circular pattern is observed on the screen.

Before indicating how to measure minute frequency variations accurately, the fundamental relationship of Lissajous figure should be reviewed. The figure seen when there is a slight variation in frequency between the two input voltages applied to an oscilloscope progresses from a circle to a straight line, to a circle to a straight line, and so on. The figure passes through two straight line portions a second for a frequency difference of one cycle a second. By using a stop watch and counting for a period of a half minute or so, it is possible to measure the frequency of the oscillator accurately even to a portion of a cycle a second as is required in practical wow measurements. In a like manner, for each frequency difference at which the meter is to be calibrated the reading of the discriminator is recorded. This plot of readings gives an accurate calibration of the wow meter. By repeating the process it is possible to calibrate the meter to read both at 78 and 33⅓ rpm. Since the microammeter used is undamped, the meter swings up and down scale in synchronism with the wow frequency during the operation of the instrument. The peak wow is half the total deflection plus and minus from the average position of the meter.

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Shoran ground station antenna installation near lighthouse in Caribbean area

Shoran for Surveying

AAF tests indicate that shoran has advantages over ground triangulation and astronomic control for many geodetic survey, photo mapping, and geophysical prospecting jobs. Operating principles, circuits, and application techniques are given

THE shoran (SHOrt RAnge Navigation) system of two ground stations or beacons, together with associated shoran-equipped aircraft, was developed primarily as a precision bombing device. As such it was used with extremely accurate results during the latter phases of the war. Shoran now appears to be one of the few military electronic developments to have practical postwar uses, and is therefore worthy of consideration as a new tool of industry.

Principle of Shoran

A shoran-equipped aircraft carries a transmitter which radiates pulses in alternate groups at two different carrier frequencies. One of the two ground stations is tuned to one carrier frequency and the other station to the remaining frequency. Reception of a pulse from the aircraft causes a ground station to act as a transponder and relay a pulse on a different frequency back to the aircraft, where it is received and displayed, and the distance to that station recorded. Since the ground beacons, called Rate and Drift stations, transmit on a common frequency, the system utilizes three different radio frequencies, all in the neighborhood of 250 mc.

Since radio waves travel in approximately straight lines at 250 mc, the theoretical maximum measurable distance from the aircraft to any one ground station will vary with the height of the plane. This distance varies from about 100 miles with the aircraft at 5,000 feet to about 280 miles at an altitude of 50,000 feet. Maximum separation of the two ground stations is thus from about 350 to 500 miles, depending upon the type of survey.

The airline distances from aircraft to ground are converted to actual point-to-point distances on the ground by mathematical formulas. Estimated probable error with unmodified shoran equipment is ± 50 feet.

As a system for accurately positioning an aircraft with respect to two fixed stations, the commercial importance of shoran becomes enormously significant. In the field of geodesy, for instance, it is often necessary to determine accurately the distance between two ground points. Use of shoran for this purpose has been successfully investigated by the 7th Geodetic Control Squadron, 311th Reconnaissance Wing, AAF, and techniques are still under development.

Shoran bombing equipment was not sufficiently accurate for geodesy. Possible sources of error were therefore studied and a knowledge of their magnitude led to more accurate determination and control of system delay times.

The path length of the radio wave traveling between ground station and aircraft is affected by weather conditions. Accurate weather data is consequently obtained and corrections made in the value used for velocity of radio wave propagation.

For surveying with shoran, the aircraft is flown to a previously specified area under the direction of the navigator. The navigator then directs the aircraft on a line perpendicular to one drawn between the two ground stations. The pilot

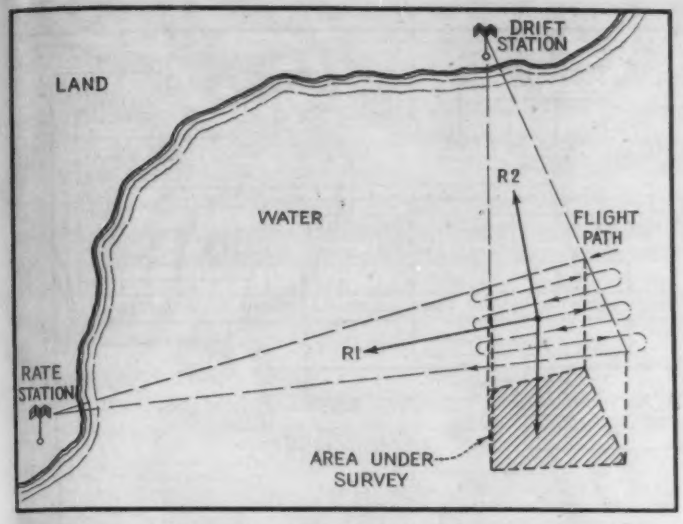


FIG. 1—Use of shoran for aerial photographic surveys. Indicator on aircraft shows airline distance to each ground station, and operator uses this data to determine deviation from desired flight path

By WILLIAM F. KROEMMELBEIN

Captain, Air Corps
307th Bomb Group, VH
MacDill Field, Florida

guides the plane on this line with the aid of a PDI (pilot direction indicator). Meanwhile the flight team operates the shoran equipment and the various data recorders. At a predetermined point the pilot turns the aircraft to a new line at an angle of approximately ten degrees to the line between the stations and now controls the aircraft with the autopilot. Necessary data for computations is then recorded on film every three seconds as the airplane continues on course. The plane then starts a crossing in the reverse manner, completing a figure-of-eight path over the center of the line between stations.

Somewhere in the accumulated data appears the minimum air-to-ground distance to the stations. This minimum is determined by fitting a curve to the various consecutive distances plotted against time by a method of least squares.

A complete geometrical figure of five ground station points is flown, measuring all sides and diagonals of the pentagon thus produced. After all network distances are measured and corrected for errors, a further least squares adjustment is made of the entire network, to obtain the most probable set of consistent distances.

Cost of Shoran Surveys

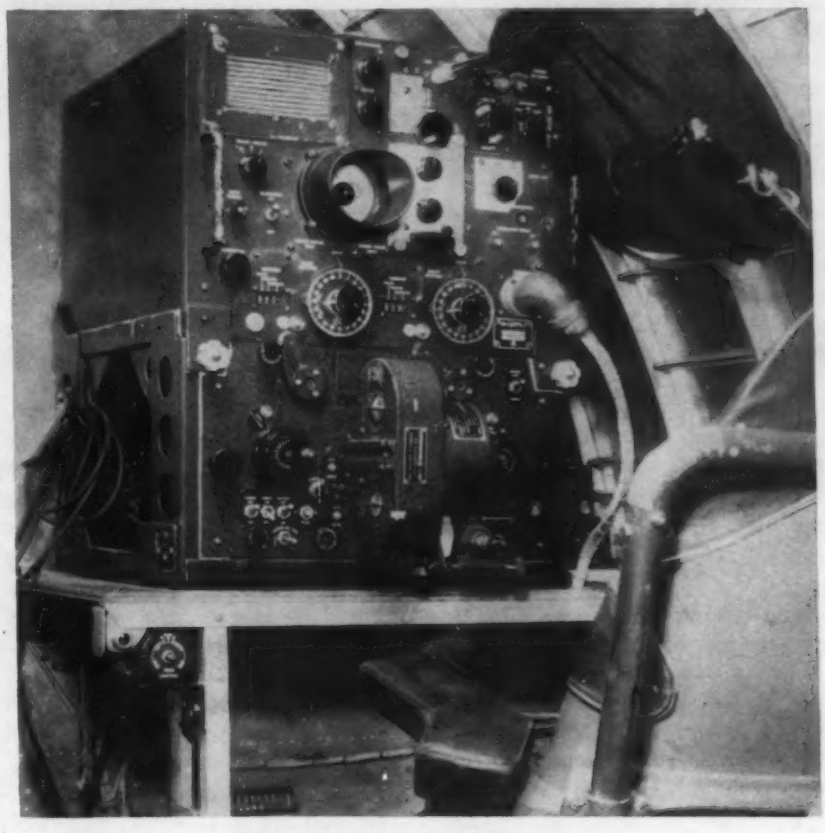
Careful operation of ground station and airborne equipment by qualified technicians, combined with accurate equipment calibration and mathematical computations, has resulted in measured distances comparable to ground survey by usual first-order triangulation methods. Further study and investigation will undoubtedly increase efficiency and reduce operation costs.

Shoran can be used cheaply to make maps up to 1-25,000 in scale, but because shoran stations are so far apart, monumenting of the surveyed area cannot be done. Then again, in island areas where locations between points cannot be seen because of great distance, or where anomalies exist that preclude accurate use of astronomic control, good surveys cannot be made quickly by any other method.

Astronomic control can be used for scales as large as 1-250,000 and no larger. Ground triangulation with monumentation becomes very expensive when the scale is of the order of 1-25,000 or larger.

Perhaps the most general commercial use of shoran is its combination with photogrammetry for aerial surveys and mapping. A possible survey of this type is shown in Fig. 1.

The usual method of photo map-



Airborne indicator and recorder for shoran

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ping involves taking a series of photographs as the aircraft proceeds along a predetermined course. Successive course lines are flown with about a 60 percent forward lap and a 30 percent side lap of photographs taken. Photo charts are then made from the series of overlapping individual photographs. The resultant chart is only as good as the accuracy with which the aircraft is flown on course.

Using shoran, course lines of the aircraft are plotted in advance, the operational team guides the aircraft along the desired course through the use of the PDI and operation of the shoran equipment, and all necessary data on position and altitude is recorded photographically while map photos are being taken.

Two general types of course lines have been flown. With reference to Fig. 1, consider the aircraft in space at the point shown, with a distance of R1 to the rate station and R2 to the drift station. As the aircraft flies its path, these distances change constantly if the path is a straight line as diagrammed. If the plane were to fly a series of arcs over the given area, one distance from a station would remain constant and the other would vary. In either case a PDI is driven from the shoran equipment to show course deviation. Both types of flight path have been used with success.

Photographs taken with shoran guidance can be used with multiplex equipment to make accurate maps quickly with scales as large as 1-25,000. These maps can be as accurate as any other existing maps of the area if the ground stations are installed carefully and tied to existing monumentation by either shoran or usual ground triangulation methods.

Geophysical Prospecting

Another outstanding wartime device, the magnetic airborne detector (MAD), was developed to locate submarines. This device, used with shoran, an aerial camera, and a radio altimeter, will allow accurate contour mapping or reduce costs of geophysical reconnaissance. The technique therefore has application

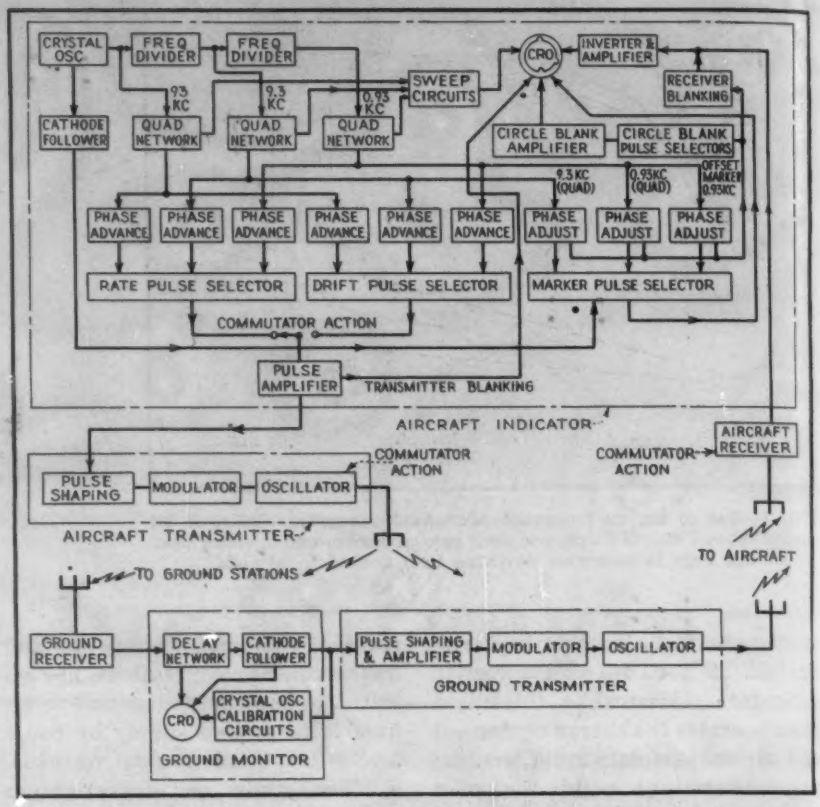

FIG. 2—Simplified block diagram of shoran system as used for aerial surveying

in the oil and similar industries. Aircraft-locating requirements for magnetic surveys are adequately met by shoran.

The camera used with MAD is a 35-mm Sonne, with image stabilization added, that records a continuous film strip of the terrain. Correlation with the magnetic record is achieved through serial numbers and edge marks on the film. The aircraft is flown on arcs from one ground station through PDI control, and deviations from course are noted on tape. A recording radio altimeter provides continuous information of the aircraft altitude. Resultant magnetic readings can therefore be plotted to a space of approximately a 100-foot cube, and the complete survey made quickly and economically. The value of such a system becomes obvious when otherwise inaccessible areas or water and island areas are considered for survey.

Shoran has also been successfully used in locating the position of ships off shore, providing the distances do not exceed line of sight from antenna to antenna. Thus accurate positioning of the craft is provided, while the desired hydrographic or geophysical surveys proceed with other associated equipment.

Technical Details

The block diagram in Fig. 2 shows the major units in airborne shoran equipment and in one of the two identical ground stations. The associated photo recorder, remote indicator, radio altimeter, and similar devices are not shown for simplicity.

Aircraft Indicator

The aircraft indicator is the heart of the entire unit. It is here that the pulses are generated and recorded, and the distances to the stations shown.

The crystal-controlled tuned-plate oscillator circuit uses a 6AC7 tube with capacitive feedback, tuned to approximately 93 kilocycles. This frequency gives a maximum directly indicated distance of 100 miles; greater distances up to line of sight require appropriate interpretation of indirect readings. The time for a 200-mile round trip of a pulse is 1,074 microseconds, hence

the pulse repetition rate must not be greater than 930 pps. Since the final indication is to be a pip alignment on a circular cathode-ray oscilloscope (cro) screen, the sweep frequency should also be 93 kc. Accuracy of alignment is facilitated by two higher sweep speeds, 9.3 kc and 0.93 kc, providing ten- and one-mile ranges.

The crystal oscillator is followed by two regenerative frequency dividers, each of which divides by ten. Referring to Fig. 3, two frequencies beat in the nonlinear 6V6, providing the output at one-tenth the input frequency. The output phase is stable, and correlated with that of the input.

The three sinusoidal output signals of the oscillator-frequency divider chain are fed to three separate quadrature networks, each designed to produce at its own particular frequency two sinusoidal signals of equal voltage, but in quadrature. One set of these signals goes to the sweep circuits, and then to the cro for generation of the circular motion of the luminescent spot at the correct rate for the scale chosen. The other outputs are fed to the variable phase advance circuits, with the 9.3- and 0.93-kc quadrature signals going also to the phase adjust circuits.

The phase advance circuits feed into rate and drift pulse selector sections, which generate the rate and drift pulses used to drive the aircraft transmitter. The phase adjust circuits feed the marker pulse selector which generates the pulses that serve as a time base, producing outward deflections of the circular sweep at the top of the cro screen.

The rate and drift received pulses also appear as deflections of the circular base line of the cro. When the shoran operator superimposes the marker, rate, and drift deflectors, the indicator dials read the distance to each station in miles.

The transmitted rate and drift pulses must be advanced in phase with respect to the marker pulses by an amount exactly equal to the time in transit of the signal to the stations plus the time delays of the equipment. This phase advancing is accomplished by accurately calibrated goniometers of the continuous type, in which the two quadrature inputs are applied to two stator coils oriented so their planes intersect at an angle of 90 degrees. The output is taken from a rotor coil, the angle of which determines the relative phase of the output through 360 degrees. There is a phase advancer for each frequency and hence range; the drift advancers and three rate advancers are separately ganged, so the resultant indicating dials connected thereto read the required distance.

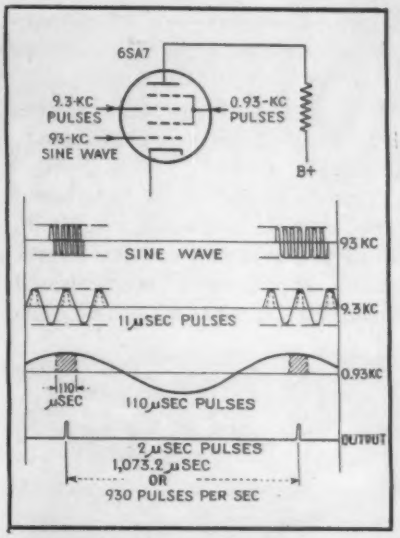

FIG. 4—Operating principle of pulse selector tube, which passes a single output pulse in its plate circuit whenever the three different pulses applied to the three grids are all reaching positive peaks at the same instant

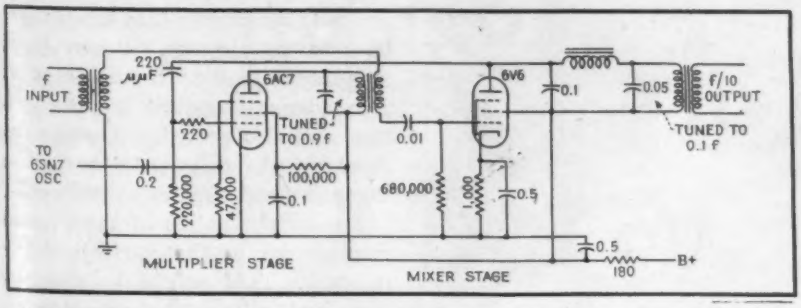

FIG. 3—Typical regenerative frequency divider circuit used in shoran equipment

Pulse Selector Circuit

The pulse selector circuit for the rate and drift channels, shown in Fig. 4, is representative of the type of circuit used in the unit as a whole. Pulse selection is a means of blocking the passage through a signal channel of all but one of the positive sine-wave peaks of the 93-kc sine-wave train which occurs during each 0.93-kc wave. The one peak passed forms a short pulse with a repetition rate of 0.93-kc or 930 pulses per second. The method allows accurate selection of the pulse desired, or accurate phasing of the pulse produced without use of complicated high-accuracy circuits.

The 6SA7 pulse selector receives three inputs from phase advance circuits. The grids are biased beyond plate current cutoff so that no current will flow unless all three grids are made more positive by a considerable amount. The output at the plate of the tube therefore consists of pulses at a repetition rate of 930 pps with a pulse width of two microseconds.

We thus have a continuous output of pulses from the selectors of the rate and drift channels. The amount of phase advance for each channel will depend upon the distance of the aircraft from the station in question, and some means must be incorporated for the transmitter following to differentiate between the rate and drift pulses. This differentiation is accomplished by a motor-driven commutator which performs a complete sequence of switching operations every one-tenth second. Actually, the two pulse outputs are used alternately for periods of 1/40 second, with periods of 1/40 second interspersed between them. This means that during one period about 23 rate pulses are transmitted, and 23 drift pulses go out the next time the aircraft transmitter is pulsed.

A pulse amplifier feeds the commutator output pulses to the aircraft transmitter. This amplifier, using a 6AC7 tube, also feeds a short blanking pulse to the control grid of the cro with such polarity

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as to cut off the beam current momentarily until the transmitted pulse has time to leave the antenna. This prevents the pulses sent out by the transmitter from appearing on the cathode-ray oscilloscope.

The phase adjust network consists of a potentiometer across diagonally opposite points of the quadrature network. Varying the potentiometer varies the phase of the signal over a 180-degree range.

The 93-kc signal for the marker pulse selector is taken from the crystal oscillator through a phasing capacitor and cathode follower. The lead is coaxial cable. The cathode follower prevents the large and variable capacitance of the cable to ground from detuning the oscillator.

Since the marker pulses have a frequency of 930 pps, one marker pulse would appear on the cro for every sweep of the 100-mile range, but only one marker for every ten sweeps on the ten-mile range, and one for every hundred sweeps on the one-mile range. Obviously the same condition would exist with respect to the received pulses. The applied solution is the use of a circle-blanking pulse selector (6SA7) and a blanking amplifier (6SN7) which blanks out all sweeps except those during which the marker and received pulses occur, and at the same time intensifies the desired sweep.

Noise voltages would be displayed on all portions of the sweep if the aircraft receiver output were fed to the cro at all times. For this reason, the receiver output is disconnected during the display of the marker pulses. This is accomplished by screen and suppressor modulation of the inverter and amplifier tubes. Blanking pulses are obtained from the offset marker network, and supplied through the receiver blanking amplifier and blocking capacitors in negative polarity with respect to the inverter and amplifier tubes so as to cut off plate current in these tubes.

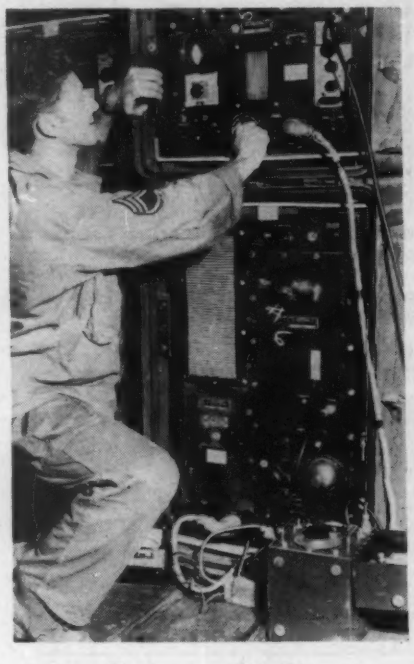
If the marker pulse and the received rate and drift pulses occur on the same sweep, alignment of the two pulses would be difficult since they would tend to become additive the closer they were brought in alignment, and it would be hard to discern the three pulses. The marker and the received pulses should occur on different sweeps, since the latent image on the tube is sufficient for alignment purposes. On the 100-mile sweep the marker occurs on each sweep, so separation is not possible. On the 10-mile and one-mile range, the marker pulse is offset by one and by ten sweeps respectively. This is accomplished through a differently phased 0.93-kc source for the generation of marker pulses in these positions, known as the offset marker.

Aircraft Transmitter

The successive rate and drift pulses are delivered to the aircraft transmitter for transmittal to the respective ground stations. In the pulse shaping section of the transmitter the pulses are amplified and steepened and their tops flattened without changing the timing of the leading edges.

The modulator driver and the modulators are of conventional design. The driver is a 3E29 twin-pentode tube with the sections connected in parallel, while the modulator consists of two tubes of the same type with all four sections paralleled.

The oscillator is a tuned-grid tuned-cathode push-pull circuit in which the grid and cathode circuit tanks are resonant transmission lines. The plates are at zero r-f voltage with respect to ground, and hence the stage does not oscillate except during the time when positive pulses are supplied from the modulator to provide plate voltage.



Shoran ground station

Oscillator tuning is adjusted by varying the electrical length of the grid line with a movable shorting bar. Another bar is used to short-circuit the line closer to the tube. A vacuum relay, excited by commutator action, switches the output from one line condition to the other, producing two output frequencies differing by 15 to 30 mc and used for triggering rate and drift station receivers respectively.

The ground station and airborne antennas are identical and are essentially vertical quarter-wave antennas working against ground. The antenna is placed directly on the aircraft, but at the ground station it is mounted on a fifty-foot plywood mast and backed by a 90-degree corner reflector.

Ground Station Receiver

The frequency range of the uhf superheterodyne receiver at the ground station is from 210 to 230 mc, with a band width of 4 mc, measured from points on the selectivity curve at which gain is 70 percent of maximum. Sensitivity is 2.5 microvolts, or 9 db above the thermal noise level. The i-f circuits are single-tuned, with their resonant frequencies stagger-tuned to the middle and both edges of the 30-mc i-f pass band. Converter and oscillator circuits are tuned to rate or drift carrier frequency by a variable transmission line controlled manually from the front panel.

Ground Station Monitor

The monitor at the ground station is interposed between the receiver for incoming pulses and the ground transmitter that sends them back to the aircraft. It provides a standard signal to the aircraft as a frequency standard for the system, and also provides a means for checking the delay of the station through fixed time delay networks.

The output pulses of the ground receiver go to the variable delay network. This artificial transmission line allows the operator to

Typical shoran ground station as set up by surveying crew, using 50-foot plywood mast to support a vertical quarter-wave antenna backed by 90-degree corner reflector

standardize the overall delay of the ground station at a predetermined value.

A cathode follower stage provides impedance transformation between the relatively high impedance of the variable delay circuit and the low impedance of the cable line to the transmitter.

The accuracy of the entire system depends upon the accuracy of the fundamental frequency of the crystal oscillators. The oscillator circuit in the aircraft is subject to drift, hence the 93.109-kc crystal oscillator of the monitor is used as a standard. The output of this oscillator passes through a frequency-dividing chain in which its frequency is divided by 100. The resulting 931.09-cycle signal is converted into short pulses of suitable power and shape, and the pulses are used to key a uhf oscillator operating at very low power. This oscillator is tuned to the same frequency as the receiver (in the 210- to 230-mc range), and the pulses are fed through a transmission line and coupling loop into the path of the received pulses. The standard pulses are also used for measuring overall ground station delay.

Ground Station Transmitter

Pulses leaving the monitor enter the shaping and amplifying stages of the transmitter. The general purpose of these stages is to eliminate noise in the signal, amplify, and shape the pulses for use by the modulator and oscillator stages.

The modulator driver and modulator are of conventional design, incorporating 3E29 tubes with the sections paralleled.

The oscillator consists of two type 4C28 triodes in a push-pull tuned-grid tuned-cathode circuit, in which the grid and cathode circuit tanks are resonant parallel-conductor transmission lines. The plates are grounded with respect to r-f, so the stage will oscillate only when pulses are supplied from the modulator. Frequency is adjusted by varying the electrical length of the grid line through the use of a movable short-circuiting bar across it. The cathode tank can also be tuned through the use of a similar shorting bar.

Aircraft Receiver

The returned pulse is accepted by the aircraft receiver (identical with ground station receiver), and the receiver output is sent to the inverter and amplifier stages in the indicator. Here the polarity of the received pulses is reversed intermittently by a polarity-reversing switch phased with the commutator action in such a way as to have the received rate pulses produce an outward deflection of the cro trace, and the drift pulses an inward deflection. This circuit also terminates the receiver blanking system.

If the shoran airborne operator operates the indicator so that the marker, drift, and rate pulses are superimposed, the mileage dials will accurately show the distance to each station in miles, tenths, and hundredths.

Installation and Maintenance

Practically speaking, the ground station equipment can be installed in about eight hours, including auxiliary living, radio, and associated equipment, by a crew of five men. It can then be operated by two men, one on the monitor and the other in radio contact with the aircraft and other stations in the net. All equipment can be carried in a jeep and trailer, making for reasonable maneuverability in rough terrain.

The aircraft equipment should be mounted in a plane having stable flying characteristics. Most Air Forces work has been done in the B-17 type.

Although not completely perfected at the present writing, shoran has definitely shown its practicability in its present state as a new tool of industry.

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RADIO RECEIVERS, to be sufficiently stable in the very high frequency portion of the spectrum, require crystal control. However to provide separate crystals for each channel is often impractical.

The need for simplicity is especially great in aircraft equipment operating in the 108 to 132 megacycle band, in which such avigational facilities as localizers and omnidirectional ranges, and such communicational facilities as tower and airways channels and domestic and international operational stations are located. An aircraft flying from coast to coast in the United States can use as many as forty frequencies in this band, if it stays on the same company airway; if the plane is interchanged between companies at terminal points on the way, more frequencies would be used. All these frequencies should be crystal controlled.

To minimize the required number of crystals both to reduce production cost and simplify servicing, a crystal saver circuit has been devised for use in the Bendix MN-85 vhf navigation system receiver.

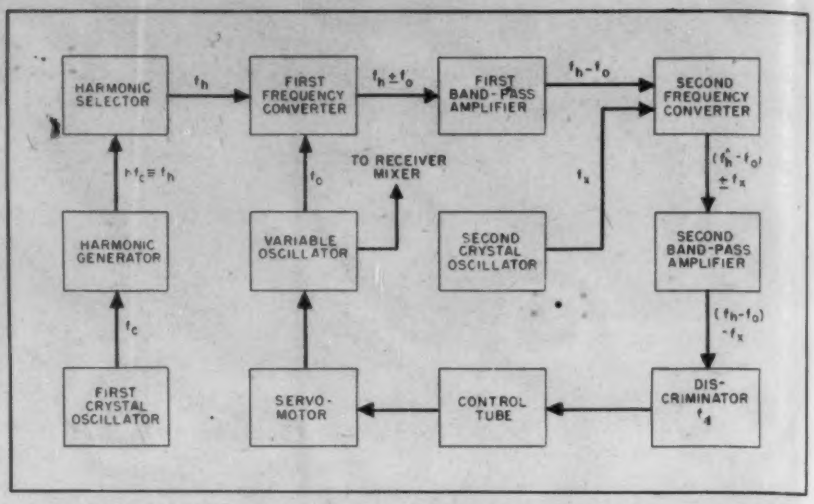


FIG. 1—Variable oscillator of receiver is stabilized on any one of 120 channels in the vhf aircraft band by means of this crystal saver circuit

Few Crystals

By W. R. HEDEMAN, JR.

Assistant Chief Engineer
Bendix Radio Division
Bendix Aviation Corp.
Baltimore, Md.

Circuit Principle

The basic problem to be solved in aircraft receiver design is to provide crystal control on the 120 channels spaced every 200 kilocycles throughout the 108 to 132 mc band. Each frequency must be maintained to better than 0.01 percent. Control must be established using a small number of self-contained crystals, retaining simplicity of design, and providing ease of maintenance and reliable performance. To meet the requirements of frequency stability, a superheterodyne receiver is necessary. This discussion is concerned only with producing the required number of crystal-controlled local oscillator frequencies to obtain the desired number of channels, and does not consider overall receiver design problems.

Consider Fig. 1; the variable oscillator is the receiver local oscillator. It is a free oscillator, capable of being tuned over the frequency band required. The radio-frequency tuning circuits are ganged and tracked with the local oscillator tuning. The actual frequency-rotation curve is unimportant, but an approximation to straight-line frequency-rotation is helpful in stabilizing tuning motor control circuits.

Some of the output of the variable oscillator is fed to the first frequency converter where it is combined with the output of the first crystal oscillator from which one harmonic is selected by means of fixed tuned selective circuits. The first band-pass amplifier passes the difference frequency of the output from the first frequency converter on to the second frequency converter into which is also fed the output from the second crystal oscillator. This oscillator may be at any one of a number of frequencies as determined by its crystal selector. The second band-pass amplifier passes the difference frequency of the output from the mixer second frequency converter. Output from this band-pass amplifier is fed to a number of fixed tuned discriminators, of the Foster-Seeley type, to obtain d-c output which feeds the control tube. The latter, in turn, operates the servomotor.

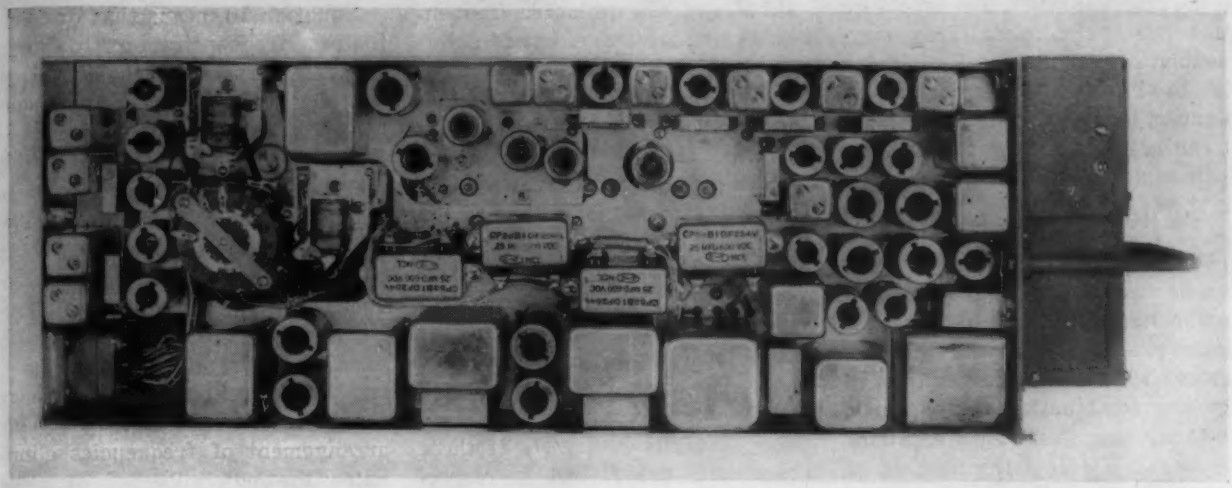
Output from the discriminator provides intelligence for frequency correction and for initial tuning. If f_o is the frequency of the variable oscillator, f_h is the frequency of harmonic selected, f_x is the frequency of second crystal oscillator, and f_d is the frequency of discriminator, then

$$f_o = f_h + f_x \pm f_d \qquad (1)$$

when the system is balanced by being on frequency. Either the plus or the minus sign can be selected as the stable frequency position by changing the sense of the servomotor. Thus by a few changes of several variables, many frequencies can be crystal controlled.

Servomotor Control

To explain the motor control circuit it is helpful to examine a simplified form such as is shown in Fig. 2, which shows only a variable oscillator driven by a motor, with a discriminator to determine the



Omnidirectional range and communications receiver has the frequency monitoring circuit described in this article at the left of the chassis. The r-f and i-f circuits occupy the upper center and right, navigation circuits extend along the lower side of the chassis. Two crystal ovens are in cans on the underside of the chassis

Control Many Channels

Local oscillator of multichannel superheterodyne receiver used for aircraft communication and navigation is crystal controlled on 120 channels by only 10 crystals. Conditions for minimum number of crystals, frequency spacing, and stability are described

oscillator frequency. The direction of motor rotation is determined by relay contacts HC, LC, their coils being energized from the output of the discriminator, through the control tube. Normal plate current of the control tube without discriminator output is sufficient to energize LC only, in which condition the motor will not run.

The discriminator output will reverse in polarity depending on whether the oscillator frequency is above or below the discriminator frequency. If discriminator output is negative, plate current in the control tube will decrease and LC will drop out, causing the motor to run in one direction. If discriminator output is positive, plate current in the control tube will increase and both HC and LC will be energized, causing the motor to run in the opposite direction. Thus the oscillator frequency is maintained equal to the discriminator frequency.

Figure 3 shows the next step in expanding the system, and shows how the plus or the minus sign for the discriminator frequency is chosen. The discriminator, instead of being fed directly from the oscillator, is fed from the output of a frequency converter. The converter mixes the output of a crystal oscillator, and the oscillator to be controlled. A low-pass filter in the converter plate circuit passes the difference frequency. If the oscillator frequency differs from the crystal frequency by the discriminator frequency, the motor does not run. The oscillator frequency may be either greater or less than the crystal frequency to obtain this result. But only one position is stable, depending upon the motor polarity. For, if the oscillator frequency is the smaller, then an increase in oscillator frequency decreases the difference between oscillator and crystal frequencies, while if the oscillator frequency is the greater an increase in its frequency will increase the difference between oscillator and crystal frequencies. Thus, by reversing motor polarity, two stable oscillator frequencies are obtained for each crystal used.

In tuning a system of this type, normal procedure is to start the local oscillator tuning from one limit of the frequency band, and to allow it to sweep the band. As its frequency changes, it will pass a position where Eq. 1 will be satisfied; here the servomotor will stop. If for any reason the frequency of the local oscillator changes, the motor again will drive to retune the local oscillator.

In order to save wear and tear on the motor, it has been found advantageous to control frequency only coarsely by the motor tuning, and to obtain fine frequency control by means of a reactance tube operated by the output from the discriminator. Whenever the range of control of the reactance tube is exceeded by slow frequency drifts, the motor restores mechanical tuning to the center of the range of control

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of the reactance tube. The reactance tube also eliminates frequency-modulation of the local oscillator due to vibration or to other causes, because, being completely electrical, it can act fast enough to eliminate such modulation.

Number of Frequencies

The number of frequencies which can be selected for control is equal to the number of combinations of harmonics, crystals, and discriminators which can be obtained. But for any combination there is one, and only one, stable local oscillator frequency. If H is the number of harmonics used, X is the number of crystals, D is the number of discriminators and N is the number of control frequencies or channels, then

$$N = 2HXD \tag{2}$$

The factor of 2 is obtained because of the $\pm$ sign in Eq. 1. In effect, two control frequencies are obtained from each discriminator, because either algebraic sign may, by choice of servomotor sense, describe a stable control frequency.

With this system of control, the most convenient design results if adjacent channels are obtained by means of adjacent discriminators, while using the same harmonic and crystal. If x is the channel spacing, then x is also the discriminator frequency spacing designated as Δf_d. If there are D discriminators, then the spacing between crystals Δf_s is

$$\Delta f_s = D\Delta f_d = Dx \tag{3}$$

After using all discriminators once, the next higher crystal frequency is selected, and the discriminators are used again. This selection is repeated until the highest frequency crystal has been used, whereupon discriminator polarity is reversed. The lowest frequency crystal then is re-employed with all of the discriminators, but this time the discriminators are used in the reverse order with respect to frequency. The same thing is done with the remaining crystals. If, then, there are X crystals, the spacing between harmonics

$$\Delta f_h = 2Xf_s = 2XD\Delta f_d = 2XDx \tag{4}$$

The spacing between harmonics is, of course, the frequency of the first crystal oscillator in Fig. 1.

Choice of discriminator frequencies is not arbitrary, but is determined uniquely once the number of crystals, the number of discriminators, and the channel spacing is chosen. This situation can be explained by Eq. 1 when it is realized that the frequency described by the nth harmonic, the highest frequency crystal, and the lowest frequency discriminator (polarity negative) must be adjacent to the frequency described by the nth harmonic, the lowest frequency crystal, and the lowest frequency discriminator (polarity positive). If these frequencies are f_1 and f_2, respectively then, from Eq. 1

$$f_1 = n\Delta f_h + f_{s\,max} - f_{d\,min} \tag{5}$$

and

$$f_2 = n\Delta f_h + f_{s\,min} + f_{d\,min} \tag{6}$$

Furthermore $f_2 - f_1 = x$ because these frequencies are adjacent. Then, subtracting Eq. 5 from Eq. 6

$$f_2 - f_1 = x = f_{s\,min} - f_{s\,max} + 2f_{d\,min} \tag{7}$$

or

$$f_{d\,min} = \frac{x + f_{s\,max} - f_{s\,min}}{2} \tag{8}$$

but

$$f_{s\,max} - f_{s\,min} = (X-1)\Delta f_s \tag{9}$$

That is to say, the difference between the maximum and minimum crystal frequencies is equal to the frequency spacing between crystals, times the number of spaces (the number of crystals less one). But from Eq. 3, $\Delta f_s = Dx$, therefore Eq. 9 becomes

$$f_{d\,min} = \frac{x + (X-1)\,Dx}{2} = \frac{x\,(1 + D\,(X-1))}{2} \tag{10}$$

Equation 10 means that discriminator frequencies are chosen uniquely once channel spacing, number of discriminators, and number of reference crystals are chosen.

Choice of harmonic and crystal frequencies is determined, to some extent, by the local oscillator. The lowest oscillator frequency should be above the highest crystal frequency. The lowest crystal frequency should be above the pass-band of the first amplifier of Fig. 1, and the highest harmonic frequency should be below its pass-band. This arrangement of frequencies eliminates the possibility of spurious conversion products in the frequency monitoring circuits. With the arrangement shown a 2-to-1 frequency coverage ratio is the maximum possible. However, several other arrangements are possible, by means of which the coverage can be extended to 4-to-1 or 8-to-1.

The usual choice of the number of harmonics, crystals, and discriminators is that which leads to the smallest total number of elements, and is accomplished if they are all equal in number. If this number is n, then, from Eq. 2

$$n = (N/2)_{\text{II}} \tag{11}$$

Equation 11 is not a necessary condition, and may be departed from if, by such departure, other and more desirable benefits can be obtained; for example, direct channel frequency reading from a simple control box.

Frequency Stability

To estimate frequency stability factors it is necessary to inquire

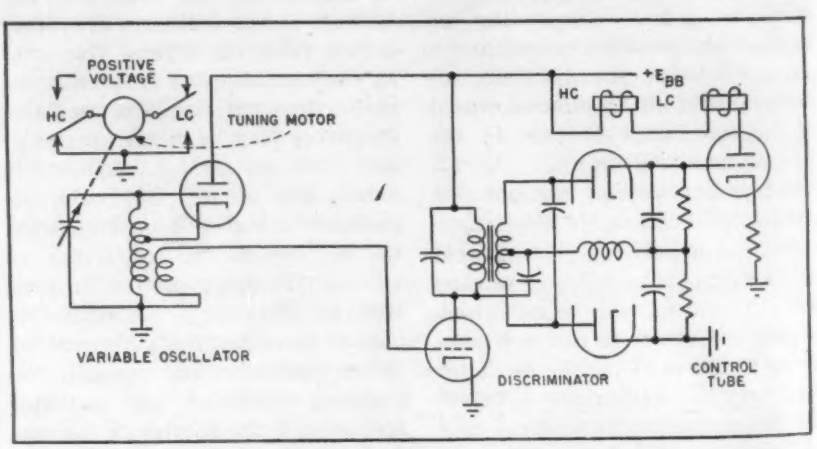

FIG. 2—Basic control circuit maintains variable oscillator at center frequency of discriminator by relay-actuated motor tuning

into the values of f_h, f_o, and f_d over the frequency band. From Eq. 10

$$f_{d\,min} = (x/2)(1 + DX - D) \quad (12)$$

Then, if $D \geq 1$

$$f_{d\,min} = (x/2)DX \quad (13)$$

From Eq. 4 $f_h = 2XDx$; therefore

$$f_{d\,min} < \Delta f_h/4 \quad (14)$$

indicating that Δf_h must be considerably less than the absolute frequency f_o because f_h is only a part of f_o. *Also* $f_{d\,min}$ must then be only a very small part of f_o, because it is less than $\frac{1}{4}\Delta f_h$, as shown in Eq. 14. Thus very large percentage errors in the absolute value of f_d will cause only very small percentage errors in f_o.

The principal frequency error, therefore, will be that owing to errors in f_h and f_o. These frequencies are crystal controlled, and can be held to ±0.005 percent individually by means of temperature controlled ovens. The resultant frequency error due to f_h and f_o collectively will also be ±0.005 percent because these frequencies are of the same algebraic sign in Eq. 1.

Considerable research into the construction of fixed frequency discriminators has revealed a method of construction which provides frequency compensation for temperature changes by means of choice of materials having the proper thermal coefficients of expansion to hold the relative positions of active parts fixed over a very wide temperature range. This construction avoids the use of temperature coefficient capacitors to obtain temperature compensation; by it and because of the high Q obtained, only ±0.2 percent of the discriminator center frequency need be allowed for center frequency drift plus reactance tube control. This error will be not greater than ±0.002 percent of the local oscillator frequency. The reactance tube will allow ±2 percent of the band covered in mechanical detuning before affecting output frequency by more than the allowable deviation. Figure 4 shows the discriminator construction.

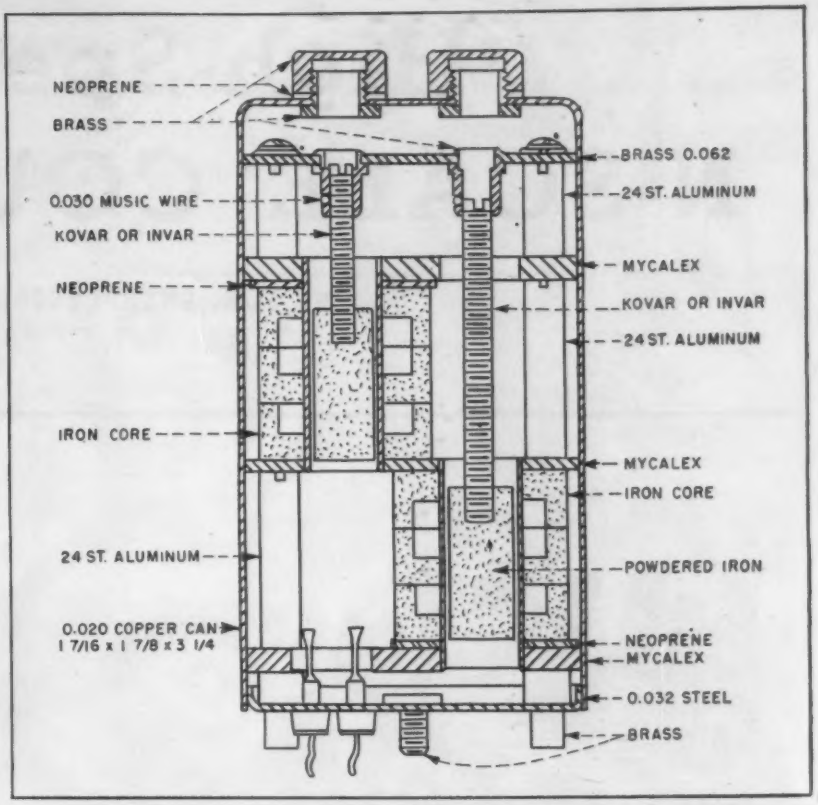

FIG. 4—Discriminator is constructed of compensating materials to insure stability

Under the worst conditions, using ±0.005 percent crystals and a ±0.2 percent discriminator, a final frequency stability of better than ±0.007 percent can be obtained by this circuit over a very wide range of frequencies.

The above circuit lends itself quite readily to remote control over a very few wires. The description of a radio frequency channel is accomplished by the selection of one harmonic, one crystal, and one discriminator. This effectively breaks channel selection down into successive steps, each step being finer than the one preceding. If it is desired to effect a remote choice of ten possibilities, then ten leads plus a remote switch can be used. In the case at hand, if there were four each harmonics, crystals, and discriminators, then four leads for each variable plus one ground lead, and three remote four-position switches will suffice for the control of 128 channels. In the practical case for the 108-132 megacycle receiver, 7 harmonics, 10 crystals, and 2 discriminators are used. The switches in this case are arranged coaxially for conservation of space and ease of reading.

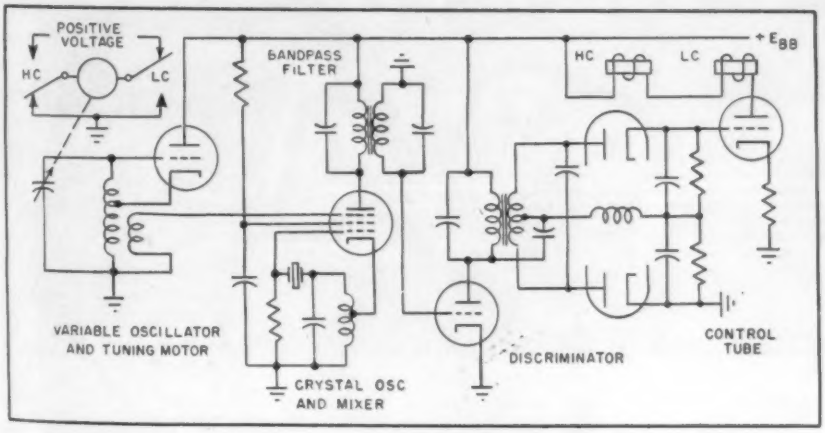

FIG. 3—Frequency stabilization is obtained by beating variable oscillator against crystal oscillator; compare with Fig. 2

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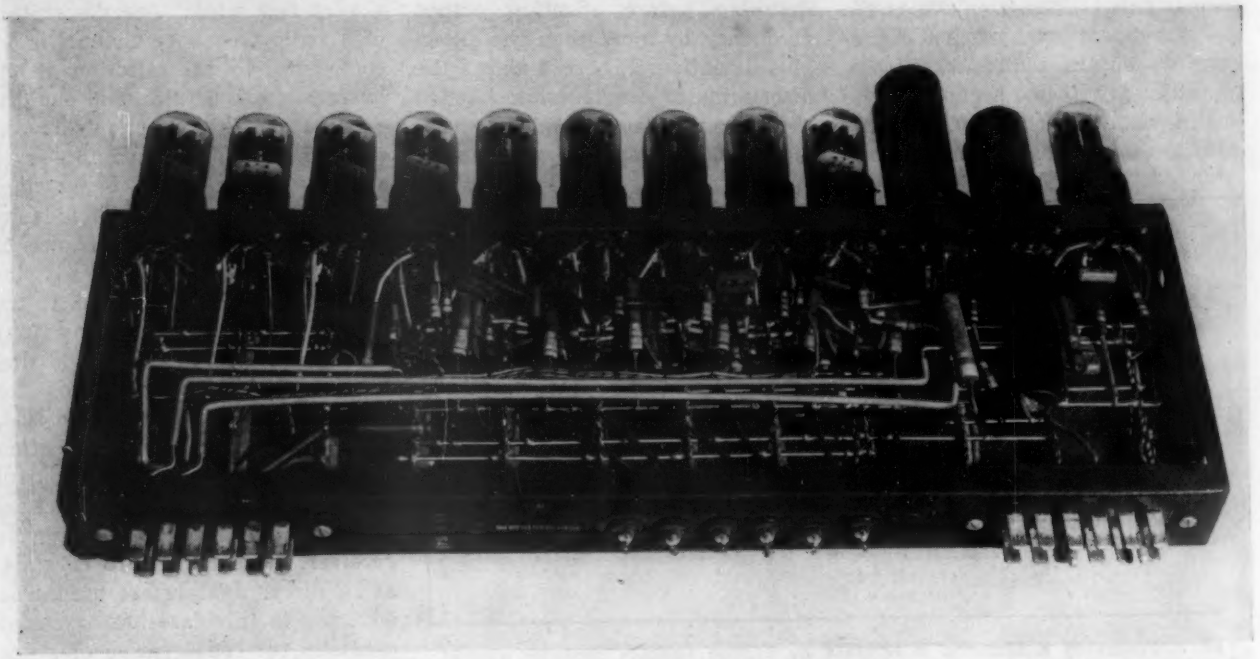
High-Speed N-SCALE COUNTERS

By T. K. SHARPLESS*
Technitrol Engineering Company
Philadelphia, Pa.

Ten stages at right form counter in this plug-in decade unit; other circuits are for carryover and transmission of count



This stepping switch unit incorporates a six-stage counter. Three tubes at right are part of input pulse-forming circuit

Basic flip-flop and scale-of-two circuits are reviewed, and extension of techniques to the design of ring and chain counters of higher scale is given. Cathode-pulsed n-scale circuit described requires no complex indicating schemes, eliminates counting errors and operates at speeds as high as 180,000 pulses per second

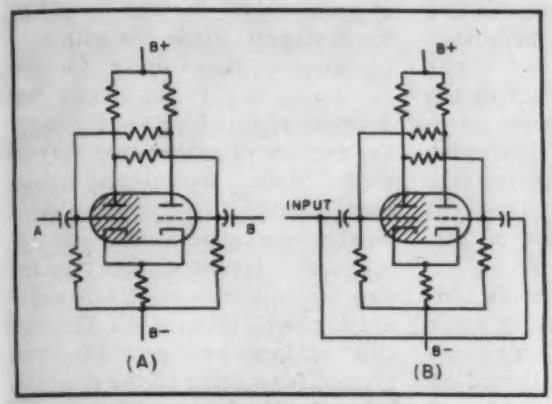


FIG. 1—Flip-flop circuit (A) is tripped by a negative pulse at input A and is reset by negative pulse at input B. Basic scale-of-two circuit (B) has two operating states, alternating from one to the other as successive negative pulses are fed to input

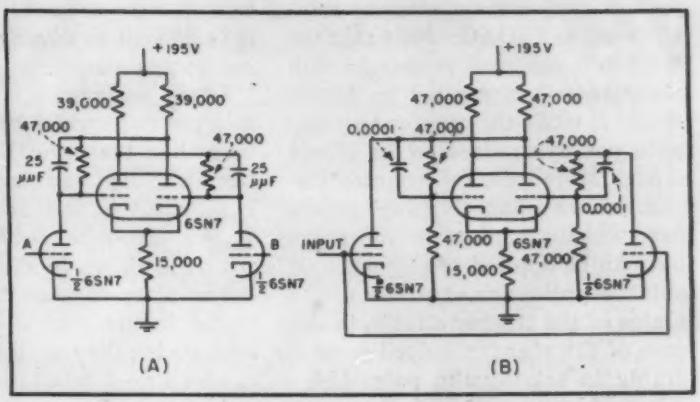


FIG. 2—Flip-flop (A) and scale-of-two (B) circuits used in ENIAC. Negative pulses are used to trip the flip-flop circuit; positive pulses trigger triodes which deliver negative pulses to plates of scale-of-two counter. This example illustrates the fact that trigger pulses of suitable shape can be applied to points other than the grids

ELECTRONIC counters have been known for a number of years and have found extensive use in physics laboratories. In these applications, their major function has been to scale down rapidly occurring pulses to a frequency suitable for the operation of mechanical counters. The fact that such scaling circuits have been used mainly for the study of radiation phenomena has meant that, in the past, electronic counters were regarded solely as laboratory equipment. In recent years, however, the application of these counters to many other problems has resulted in the production of several of them for the general market by a number of manufacturers.

The first publication of a counter circuit intended for commercial production was made in 1944 by Potter.[1] In 1939, Perry Crawford, in a thesis written at MIT, proposed the use of such counters in a computing device. RCA Research Laboratories, in 1941, examined such applications in a computer for a gun director.

Counter Applications

The ENIAC, first large-scale, practical, computing device making use of electronic counter circuits, was designed and built at the Moore School of Electrical Engineering of the University of Pennsylvania and put into operation in December 1945. This machine, involving 300 electronic counters, was built for the Army Ordnance Department and marked a tremendous advance in the art of computing.

Electronic counters are usually derived from two basic types of trigger circuit, the flip-flop and the scale-of-two counter. Both of these circuits are examples of the Eccles-Jordan trigger circuit, first published in 1919.[2]

To explain the operation of the flip-flop, Fig. 1A, assume the lefthand triode section to be conducting, and let this condition be designated as state 1. A negative pulse appearing at *A* will cut off the lefthand triode; the positive signal appearing at its plate will cross over to the opposite grid and turn on the righthand section. The negative signal from this plate is fed back to the lefthand triode and keeps it cut off. The circuit is now in state 2. A subsequent negative pulse on *A* will have no effect. However, a negative pulse appearing at *B* will reset the circuit to state 1.

Pulse Dodging

The scale-of-two counter is shown in Fig. 1B. It will be seen that a negative pulse applied to the input tends to hold the righthand triode cut off while the positive signal from the plate of the lefthand tube is trying to turn it on. Thus, in converting a flip-flop to a scale-of-two counter, the problem arises of producing in the crossover a signal

* Developments reported were made while the author was Technical Director of the Digital Computing Program at Moore School of Electrical Engineering, University of Pennsylvania.

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that will override the externally applied signal. This problem can be called the pulse-dodging problem. It is apparent that the shape and magnitude of the tripping pulse in a counter are of utmost importance, although in flip-flop applications such is not the case.

Figure 2 shows the flip-flop and scale-of-two counter circuits actually used in ENIAC. Note that the flip flop is designed to operate with negative pulses applied to inputs *A* and *B* while the counter operates with positive pulses on its single input. Moreover, the counter circuit shows that tripping pulses need not be applied to the grids but can be applied to any suitable point. Application of pulses to the plates of the trigger circuit, in the case of the counter, helped considerably in solving the pulse-dodging problem mentioned above. A number of practical circuits for both flip-flop and scale-of-two counter applications have been devised.[3]

Once a counter having a scale of two has been designed, the extension of the scale to higher numbers immediately suggests itself. Scale-of-*n* counters can be made by merely cascading stages of scale-of-two counters, as done by Wynn-Williams.[4] With this arrangement, *n* can only be a power of two unless special tricks are resorted to as in the Potter counter.[1] As a result, the conducting triode combinations are not linear, so that it is difficult to display the numerical counts simply.

Lewis[5] designed a circuit of one tube per stage which behaves essentially like the basic Eccles-Jordan circuit, in that one conducting tube is sufficient to keep the others cut off. A five-tube example of this circuit is shown in Fig. 3.

The plate of each tube is connected to the grid of every other tube, giving the circuit stable states in which *n*—1 tubes are turned off and one on. Proper progression of carryover in the counter is achieved by use of capacitance coupling between any one stage and the next, in parallel with the direct resistance coupling which is used to hold the circuit in its particular state. Since the last tube is connected to the first in this same manner, the circuit is called a ring counter.

The major objection to counters of this sort is that each plate and each grid is loaded by *n*—1 resistors. Thus, as the number of stages increases, the device becomes quite complex. Morever, this loading of each stage results in a reduction of gain around the loop formed by the *n* stages. Since this gain must be greater than unity for the counter to step, it can be seen that counters of this type are limited in the number of stages that may be used. With presently available vacuum tubes, five stages are about all that seem practicable.

Counter circuits of this type can also be built with *n*—1 tubes conducting and 1 tube cut off. Although this arrangement provides more current for cutting off the one tube, it has the disadvantage that the circuit may run away, for there may exist one moment when all tubes are on and the phase shift around the loop may be some multiple of 360 degrees at a particular frequency so that oscillation can occur.

Lewis combined a scale-of-two with a scale-of-five counter of the type described above, to produce a scale-of-ten counter. Such arrangements have the disadvantage that the operating state of the circuit at any moment is not directly indicated but can be known only by reference to its binary and quinary parts.

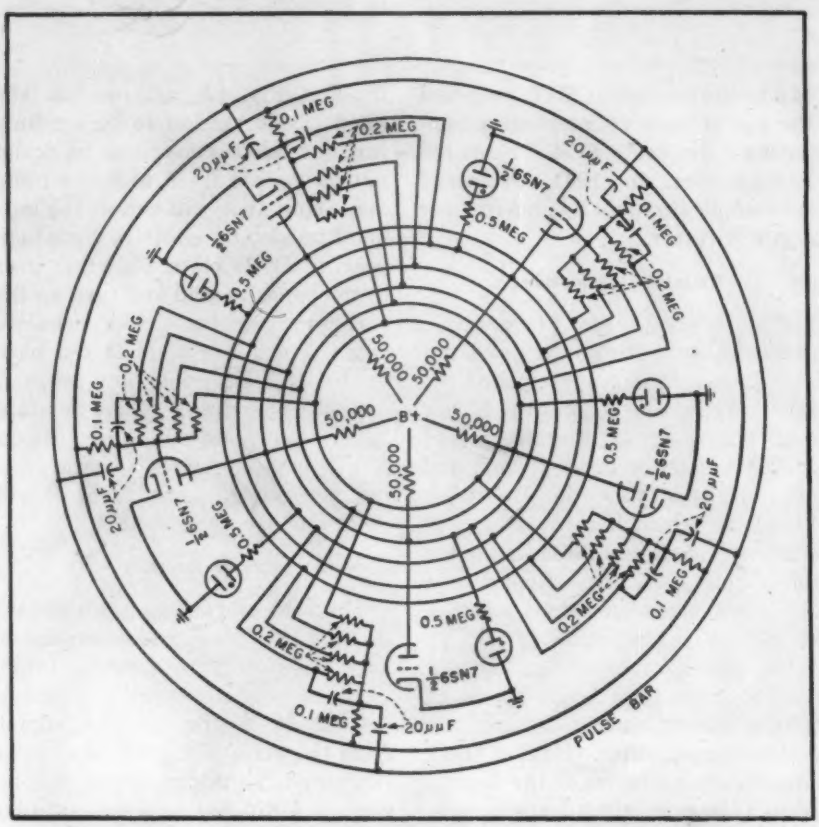

FIG. 3—Lewis five-stage ring counter. Successive pulses fed to pulse bar step the counter through five states; on sixth pulse the counter recycles

n-Scale Counters

In ENIAC, n-stage counters are formed using two triodes per stage in standard trigger circuits. Such counters are found in scales of six, nine, ten, fourteen, and twenty.

Figure 4 shows this type of circuit generalized for *n* stages. Consider the circuit to be operating with the shaded tube sections conducting as shown. The counter is now in its first stable state with a positive potential at the lefthand plate of the initial or 0th stage. This condition is indicated by the lighting of the 0th neon glow lamp. No other lamp is lit since the currents drawn through the conducting lefthand tubes are sufficient to drop the plate potentials below the ignition point of the glow lamps. The application of a negative pulse

to the lefthand cathode of the 0th stage turns that triode on and the trigger action of the stage cuts off the righthand triode producing a positive signal at its plate. This signal, transferred through C_2, turns on the righthand section of stage 1, thus triggering this stage into the condition that previously existed in stage 0. Successive pulses applied to the pulse line produce similar stepping from stage to stage down the line. If, as shown in the diagram, the last stage is connected back to repeat the cycle, a ring counter results.

As in all previously mentioned counters, the pulse-dodging problem is present, for the negative pulse on the cathode which turns on the lefthand side of an abnormal stage also tends to keep on the lefthand side of the subsequent stage which it is desired to change. That this does not occur is due to the fact that the crossover signal through C_2 is of such amplitude and duration as to override the effect of the negative input pulse. For this overriding action to take place, it is necessary that the applied pulse shape be maintained and its amplitude controlled within quite close limits. This pulse shape and amplitude control is achieved by incorporating as part of each counter the pulse standardizing circuit of Fig. 5.

The fact that each tube in a counter is operated as a binary device, thus having only two states: conducting and nonconducting, is used to advantage. Though the applied pulse, circuit parameters, or bias voltages may vary considerably in amplitude, so long as the grid is driven to cutoff on the one hand and to zero or a slightly positive value on the other, the plate current has only two values. This principle is of basic importance in counter design, since reliability of operation is achieved by minimizing the effect of changing circuit parameters.

Design Considerations

A counter circuit should be so designed that coupling between stages is effected without the use of extra tubes or buffers. Furthermore, it is desirable to arrange the circuit so that there is a minimum

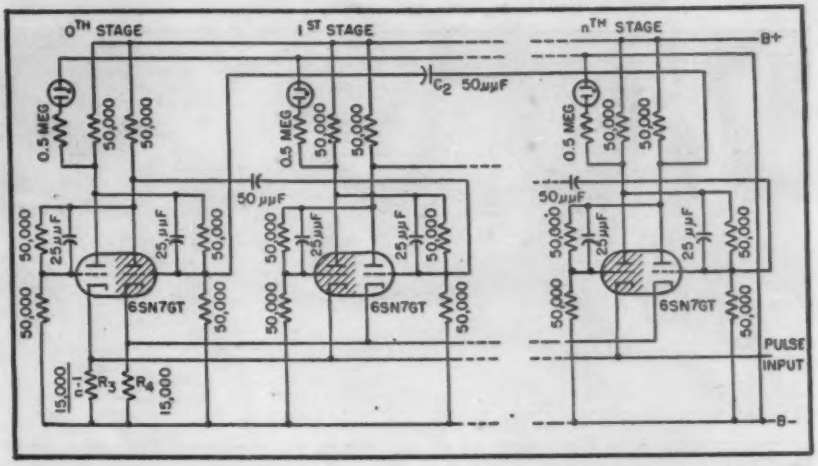

FIG. 4—N-stage counter differs from cascaded binary systems in that cathodes of trigger circuits are interconnected with pulse input causing successive stages to trip in linear sequence.

of connections and so that not too many of these go to any one element of the tube, such as the grid. There must be in the decade counter, for example, internal coupling, connections between stages, connections to the pulse bar, connections to the neon indicating lamps, static output connections, and reset connections for clearing the counter. One disadvantage in grid pulsing lies in the fact that the grids are already used for the internal connections so that using them also for the pulse bar connections loads them too heavily.

A counter circuit may be so arranged that it can operate in modes other than the one desired. Thus, if a stable state of a decade counter consists of 9 tubes off and 1 tube on, it may be that the counter can also operate with 2 tubes on and 8 tubes off. If a counter is expected to operate in the first mode, but happens to get started operating in the second mode, then though the circuit will count, the output voltages will be incorrect and the counter useless. The counter of Fig. 4 is capable of only one mode of operation because of the relation between R_3 and R_4.

In computing machine applications, a counter must be completely reliable, that is, it cannot be permitted to lose a single pulse. Some 300 counters of the type shown in Fig. 4 have been used in ENIAC for the past year and have met this criterion of reliability. Production models operate at a maximum count rate of 180,000 pulses per second or

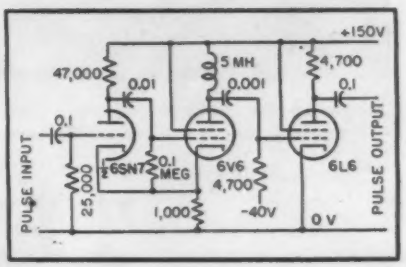

FIG. 5—Pulse-forming circuit for cathode-pulsed counter of Fig. 4. This circuit controls shape of input pulses to insure correct pulse-dodging action

better and count at 100,000 pulses per second with applied voltage ranging from 90 to 500 volts. They are quite insensitive to variations in circuit parameters and particularly to changes in tube characteristics. Indeed, tubes of twice the plate resistance of 6SN7's have been inserted with the result that the counters operated at about 140,000 pulses per second. Since they are designed to operate at 100,000 pulses per second, their use was not impaired. Present electronic computing machine research has produced a number of counting circuits that are reliable at rates up to 2 or 3 million pulses per second.

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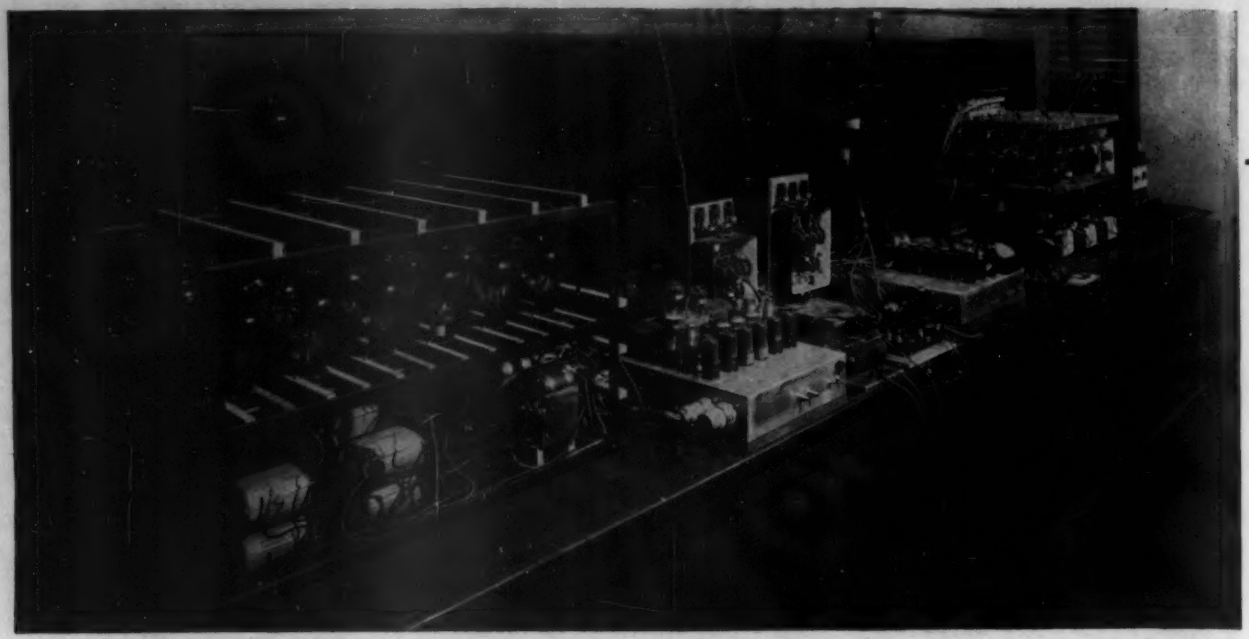

Frequency-changer power circuits include parallel-inverter type, left, and cycloconverter, extreme right. Frequency and phase control units are in the center. Connections between control circuits synchronize the two systems to permit parallel operation

THYRATRON Frequency Changers

Designed to permit parallel operation of three-phase aircraft alternators driven at unequal and varying speeds, the converter and control circuits described here produce three-phase power having constant frequency and regulated voltage. Characteristics of two types of power units are compared

By O. E. BOWLUS and P. T. NIMS

Chrysler Corporation
Detroit, Michigan

ONE OF THE interesting problems in connection with modern large aircraft is the provision of adequate electrical power. The number and size of electrical loads increases yearly as new models of gun turrets, radar, automatic controls, and radios are installed. The present systems use 24 volts d-c, but for weight saving with these increased loads, there is considerable interest in 120-volt 3-phase a-c systems.

A major obstacle to a-c operation of the heavier motor loads is the difficulty of obtaining large blocks of power economically. For fuel economy, it is desirable that aircraft generators be driven by the main engines, and for reliability the power should be available from any or all of the engines of a multi-engined aircraft. This implies that the outputs of several main generators be paralleled at the load bus. Paralleling is difficult, as even with the airplane's engines synchronized well enough to reduce vibration the generators are still a long way from the exact synchronism demanded. As the generator horsepower is only a small part of the total engine output, the synchronizing torques of the generators are inadequate to hold the system together. In addition, the engine speed for most efficient operation varies with flight conditions and would seldom be that required to give the desired 400-cycle output from the generator.

This situation calls for some method of obtaining synchronization and correct frequency in the electrical system. Mechanical or

hydraulic methods might be used to give a constant-speed drive for the alternators, or the alternators could be directly connected to the aircraft engines and the necessary frequency change obtained electronically. The latter method was chosen as the basis for some experimental work which Chrysler Corporation Engineering Division was asked to do on 4-kva units for the parallel operation of aircraft type alternators. Two units were built and successfully operated in parallel at 400 cycles with input frequencies varying from 300 to 900 cycles[1]. The photograph shows the two units set up for bench test. The electronic frequency changer used consisted of a power circuit using eighteen grid-controlled gas-filled rectifiers and a frequency-control circuit with fourteen assorted receiving type tubes. The control circuit provided three-phase, 400-cps, square waves.

Two power circuits were tested, one of the parallel-inverter type[2], the other of the cycloconverter type[3] and certain differences in their operation noted. For three-phase operation, the cycloconverter offered advantages in weight, efficiency, and power factor of the generator. If only single-phase 400-cps power is needed the parallel inverter has possibilities.

Cycloconverter Power Circuit

The complete power circuit of the 4-kva test unit is shown in Fig. 1. The alternator available was rated at 30 volts output, so that a delta-wye connected step-up transformer was used to supply approximately 200 volts to the tubes. The current from one phase of this transformer passes through a load-division current transformer, one of the six tubes connected to it, half of a reactor, a series capacitor, and one phase of the load. As the neutrals are not interconnected, the current

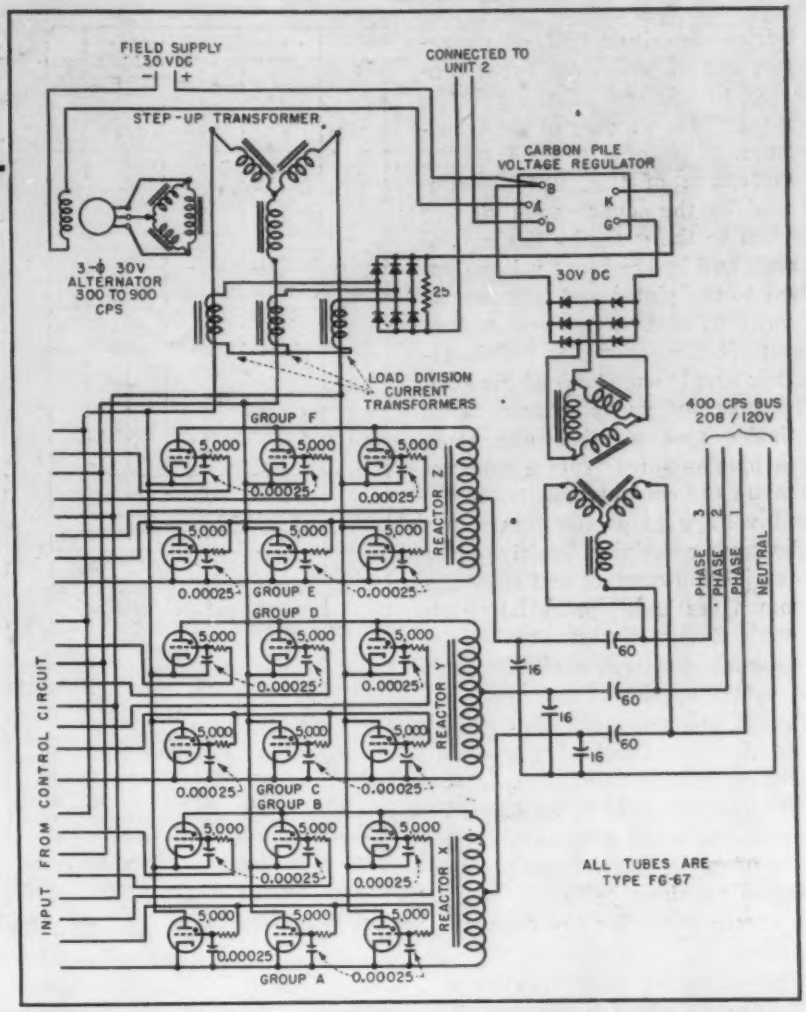

FIG. 1—In the cycloconverter, each phase of the step-up transformer secondary supplies voltage to three pairs of thyratrons. Output frequency is held at 400 cycles by auxiliary control circuit that determines thyratron firing sequence

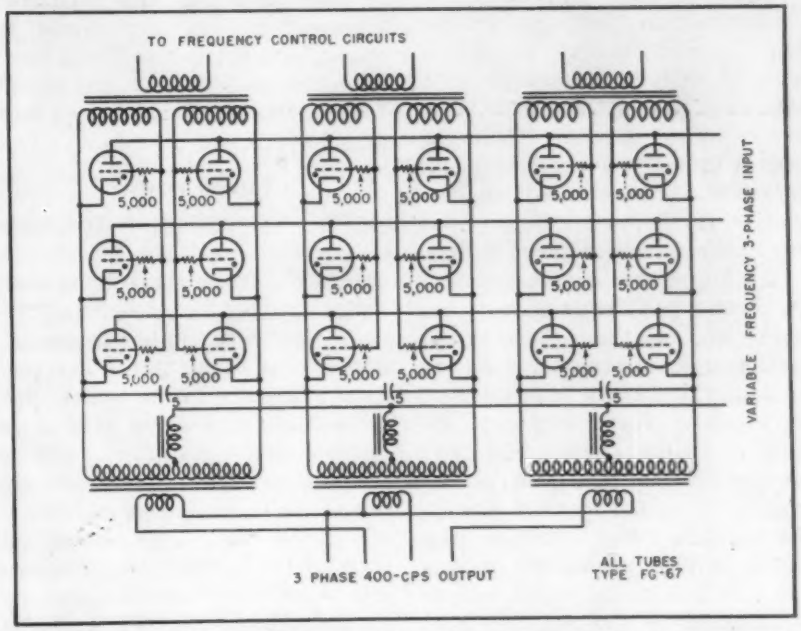

FIG. 2—Three-phase parallel-inverter shown here consists of three interconnected single-phase units with phase sequence determined by circuit of Fig. 4. Losses in transformers and chokes make this circuit less efficient than cycloconverter

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by a single-tube inverter circuit. Referring to Fig. 4, capacitor C_1 is rapidly charged through tube V_1 to somewhat above line voltage by virtue of the inductance of the primary of transformer T_1. Since the cathode at this instant is positive with respect to plate and the grid is held negative with respect to cathode, the tube is extinguished. Capacitor C_1 then discharges through resistors R_1, R_2, until the combination of plate-to-cathode and grid-to-cathode voltages are such as to fire the tube. Capacitor C_1 is again rapidly charged. The cathode voltage has a sawtooth waveshape with sharp rise and slow decay.

The sawtooth voltage is fed through capacitors C_2, C_3, C_4 at the grids of tubes V_2, V_3, V_4 in the three-tube switching circuit. These tubes are biased in such a manner that at any instant two are conducting while the third is cut off. Each pulse of the sawtooth voltage causes the tube which is cut off to conduct and causes one of the other two tubes to cease conducting. The cut-off condition passes from one tube to the next in definite sequence.

In Fig. 4, assume tube V_2 to be nonconducting and tubes V_3 and V_4 to be conducting. The plate of tube V_2 is near supply potential and, by means of the voltage dividing resistors R_4 and R_{11}, tends to hold the grid of tube V_3 at or above cathode potential. Also, by means of resistors R_{11} and R_{20}, the plate of tube V_3 tends to hold the grid of tube V_4 at or above cathode potential. Tubes V_3 and V_4 are held conducting. When conducting, the plate potential of tubes V_3 and V_4 is approxi-

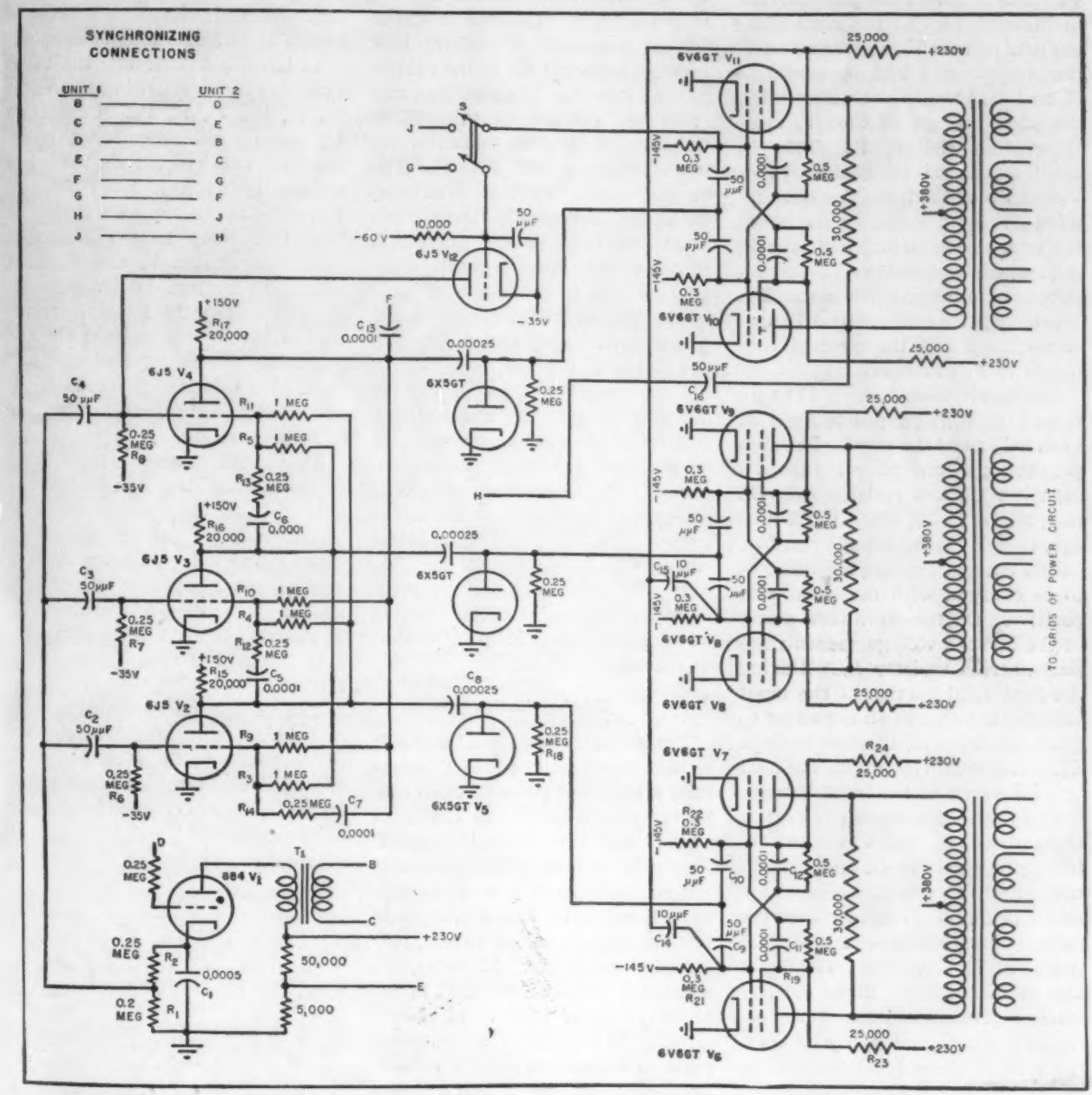

FIG. 4—In the control circuit, a 2,400-cycle relaxation oscillator drives a ring-of-three counter that develops three 800-cycle square-wave output voltages having 120-degree phase relationship. Each of these voltages drives a flip-flop circuit coupled to the thyratron

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returns through another load phase, a series capacitor, half of its reactor, one of the three tubes connected to the end of the reactor, and the phase winding of the transformer.

Operation of the tubes is controlled by the square-wave voltage applied to the grids by the control circuit and by the input voltage applied to the plates and cathodes as shown. Consider group *A* and group *B* for example, which together supply one phase of the load. The tubes of group *A* have their cathodes tied together and their grid bias supplied from a common point in the control circuit. If the grid voltage is positive, then the tube having the most positive plate potential will conduct and raise the common cathode potential high enough to cut off the other tubes. As the input voltage varies through its cycle, another tube anode in group *A* becomes more positive and it conducts, cutting off the previously conducting tube.

When a half cycle of the 400-cycle output frequency is completed, the grids of group *B* are made positive relative to their cathodes. Since the group *B* anodes are connected together, the tube with its cathode connected to the most negative input line conducts and also prevents conduction in the other two tubes.

Commutation

Commutation between groups, that is, extinguishing a tube of group *A* when a tube of group *B* fires, is produced by reactor *X* in the following manner. When a tube in group *A* is conducting, the cathode end of reactor *X* is positive relative to the center tap. However, when a tube of group *B* fires, it instantly makes the anode end of the reactor positive relative to the center tap, and the cathode end is made temporarily negative due to the autotransformer connection of the reactor. The duration of the negative swing is dependent upon the size of the series and shunt capacitors in the output circuit. The negative swing must last long enough to permit the tubes to deionize. This deionization appears to be hastened by the negative grid voltage applied during the off cycle for group *A*[4, 5].

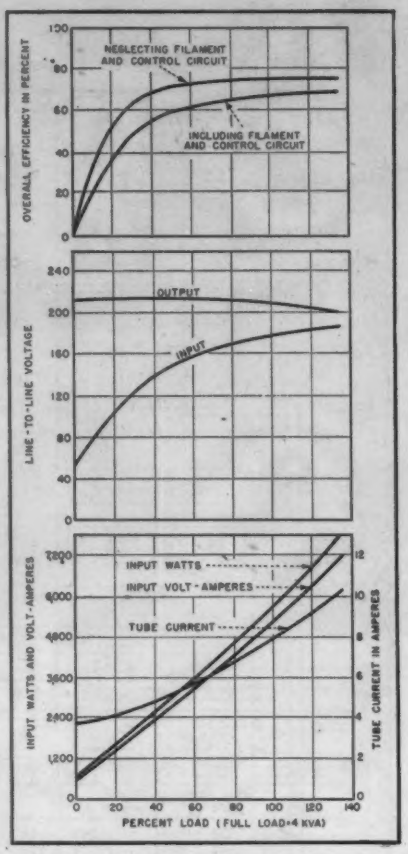

FIG. 3—Performance curves for cycloconverter power circuit

It is interesting to note that for the special case when the input frequency exactly equals the output frequency, six of the eighteen power tubes will be completely inoperative. If sustained operation is possible under this condition, then either the tubes should be chosen with ample capacity or some provision made to shift the output frequency slightly to prevent sustained operation.

Parallel Inverter

When operated as a frequency changer, the parallel inverter is basically a device using 3-phase input at one frequency to give single-phase output at another frequency. The anodes of six tubes are connected in pairs to the source, and the cathodes in two groups of three to the output transformer. Figure 2 shows how three such units are connected to give 3-phase output and shows also the neutral return for the supply lines. Tests on this circuit showed satisfactory operation but larger I^2R losses in the various transformers and chokes. The circuit also required an output transformer as well as the series reactor.

The overall efficiency, input voltage variation and power input of the cycloconverter are shown in Fig. 3.

Parallel Operation

The two types of frequency changers operate well in parallel, with load division on the alternators controlled by the voltage regulators as in a d-c system. Heavy resistive loads, even to the point of short circuiting the output terminals, were carried with ease. Inductive loads require correction to nearly unity power factor for satisfactory operation, because of effects on both wave form and commutation. One-quarter hp motors start and operate normally. A 3-hp motor will start and operate normally, provided there is ample resistive load on the bus to stabilize the system.

Control Circuit

The control circuit, as mentioned, supplies a 3-phase 400-cycle square wave for the power tubes. It is these control circuits which are synchronized for parallel operation of two frequency-changer units as shown in Fig. 4. The basic frequency is determined by an 884 gas triode which discharges 2,400 times per second. These pulses are fed to the grids of three 6J5 triodes connected in a ring-of-three counter circuit[6]. Each 6J5 goes through an on-off-on cycle 800 times per second, and each tube operates 1/2,400 of a second after its predecessor in the ring. This gives 3-phase voltages at 800 cycles.

The final stage of the control circuit comprises three pairs of 6V6GT pentodes connected in a modified Eccles-Jordan circuit. The cathode, grid, and screen of each tube are in the flip-flop circuit and the anode is connected to the transformer which forms the output connection of one phase of the control. The tubes in each pair conduct alternately and thus produce in the transformer a 400-cps square wave of voltage. The vacuum tubes used in these counting circuits operated with much more stability than the gas triodes first used.

Output frequency is determined

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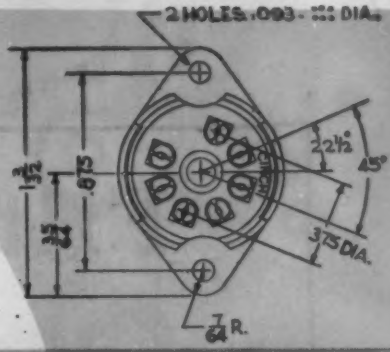

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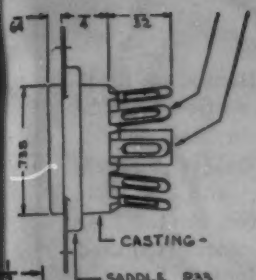

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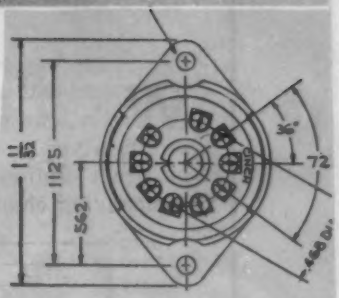

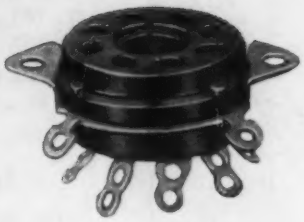

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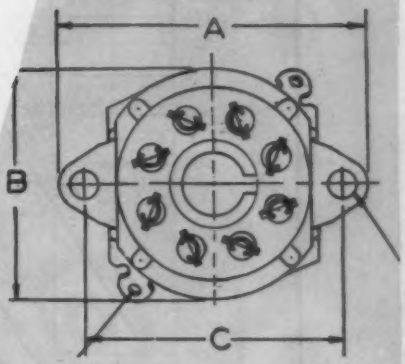

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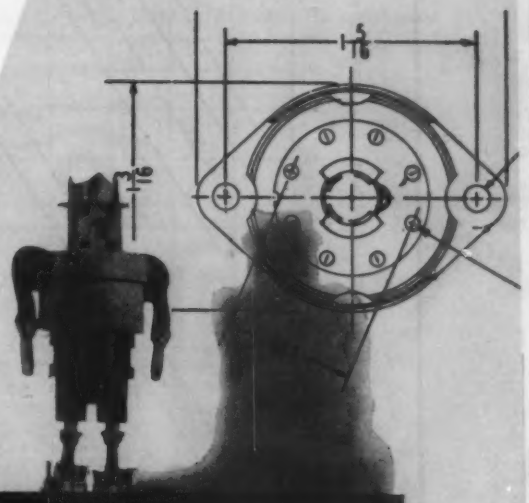

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mately one-third the supply-to-cathode voltage. By means of resistors R_2, R_3, and R_5, the grid of tube V_2 is held sufficiently negative with respect to cathode to block the flow of plate current. When the next upward sawtooth voltage pulse is transmitted through capacitors C_2, C_3, and C_4 to the grids of all three tubes, the grid of tube V_2 is made less negative with respect to cathode causing plate current to flow. As soon as plate current flows, the plate voltage drops by virtue of resistor R_{12}. This drop, being transmitted to the grids of tubes V_3 and V_4, tends to reduce the plate current in these tubes. At the same time, the grid of tube V_2 is given an additional downward kick by capacitor C_6 and resistor R_{13}. Consequently, the plate voltage of tube V_2 rises faster than that of V_4. Tube V_2 assumes control by holding tubes V_3 and V_4 conducting. The next upward sawtooth voltage pulse renders tube V_3 conducting and tube V_4 is selected by capacitor C_6 and resistor R_{15} to become nonconducting. The next pulse renders tube V_3 nonconducting, and the process continues in this manner.

The plate-to-cathode voltage from tube V_2 is clipped to form an inverted saw-tooth wave. The clipping circuit consists of tube V_9, capacitor C_{12}, and resistor R_{19}. On the positive swing of the input voltage, tube V_9, being a diode rectifier, passes current causing capacitor C_8 to be charged with the input side positive. On the downward swing of the input, a voltage suddenly appears across resistor R_{19}. During the horizontal portion of the input voltage, the charge on capacitor C_8 gradually leaks off through resistor R_{19}. The cycle repeats on the next upward swing of the input voltage.

The inverted sawtooth voltage is transmitted to tubes V_6 and V_7 through capacitors C_9 and C_{10}. In the flip-flop circuit comprising tubes V_6 and V_7, consider first the part connected to screen grid, control grid, and cathode. The tubes are so biased that, in the steady state condition, one tube blocks current while the other passes current. Each input pulse from the clipper circuit reverses the condition on the tubes, that is, the one which was blocked is made to pass current and the one which was passing current is made nonconducting.

Assume tube V_6 blocked and tube V_7 conducting. Then the screen grid of tube V_6 is near line potential and the control grid of tube V_7 is held at or above cathode potential by means of the potentiometer circuit consisting of resistors R_{19} and R_{20}. Likewise the screen grid of tube V_7, because of the drop across resistor R_{24}, holds the control grid of tube V_6 below cutoff by means of resistors R_{20} and R_{21}. The next negative pulse from the input voltage drives the control grid of tube V_7 negative, reducing the flow of screen current. The rise in screen voltage transmits a positive kick through capacitor C_{13} to the control grid of tube V_6. The resulting rise in screen voltage on tube V_6 is transmitted through capacitor C_{11} to the control grid of tube V_7. The process once started, continues until the current is transferred from one tube to the other. A square voltage wave is obtained between screen grid and cathode.

The primary of a center-tapped transformer is connected between the plates of tubes V_6 and V_7 with the centertap connected to positive d-c line voltage. By connecting a resistor across the primary, a square output voltage can be obtained. Four secondary windings are provided for connection to the control grids of the FG-67 power tubes.

It will be noted there are three separate flip-flop circuits. Action of the other two is identical to that of the one explained.

Synchronization

The secondary of transformer T_1 in the plate circuit of tube V_1 transmits a transient pulse through connector pins B and C to connector pins D and E in control circuit 2. This pulse is further transmitted to the control grid of tube V_1 in control circuit 2, in such a manner to fire the tube, unless, of course, it is already conducting. Likewise, the secondary of transformer T_1 in the plate circuit of tube V_1 in control circuit 2 transmits a transient pulse to the control grid of tube V_1 in control circuit 1. Whichever tube fires first fires the other. The tube with the shortest period will determine the output frequency.

Tube V_{12} is used to synchronize the three-tube switching circuits in the two control circuits. Capacitor C_{13}, attached to plate of tube V_4 in control circuit 1, transmits a pulse to grid of tube V_{12} in control circuit 2 when synchronizing switch S is depressed. When tube V_4 in control circuit 1 is blocked, tube V_{12} in control circuit 2 is made conducting. Tube V_{12} holds the grid of tube V_4 in control circuit 2 below cutoff. In this manner, tube V_4 in control circuit 2 is made to be nonconducting during the same period tube V_4 in control circuit 1 is nonconducting. Once the circuits are brought into step, switch S may be opened.

In the flip-flop circuit, the tubes must fire in the following sequence: V_6, V_8, V_{10}, V_7, V_9, V_{11}. Capacitors C_{14} and C_{15} hold them in this sequence. Three of the six tubes are conducting at any given instant. From the above sequence it may be seen that when tube V_{11} becomes conducting, tubes V_6 and V_8 must be nonconducting. When tube V_{11} fires, a downward pulse is transmitted through capacitors C_{14} and C_{15} to the control grid of tubes V_6 and V_8, rendering the tubes nonconducting if they are not already in that condition.

There still remains a possibility of the flip-flop circuit in control circuit 2 being 180 degrees out of phase with the flip-flop circuit in control circuit 1. To bring them in step, a small capacitor C_{16} is connected from the plate of tube V_{12} in control circuit 1 through switch S to the grid of tube V_{11} in control circuit 2.

The three-tube switching circuit and the six-tube flip-flop circuit are synchronized by the same switch S. Both control circuits are connected so that either may be synchronized to the other.

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(4) W. G. Shepherd, Deionization Conditions in a Harmonic Generator Employing a Gas Tube Switch, *Proceedings IRE*, p 66, Feb., 1943.

(5) M. M. Morock, Voltage Impulses for Thyratron Grid Control, *GE Review*, p 288, June 1934.

(6) W. B. Lewis, "Electrical Counting", Cambridge, England, p 91, 1942.

Filter Ripple Chart

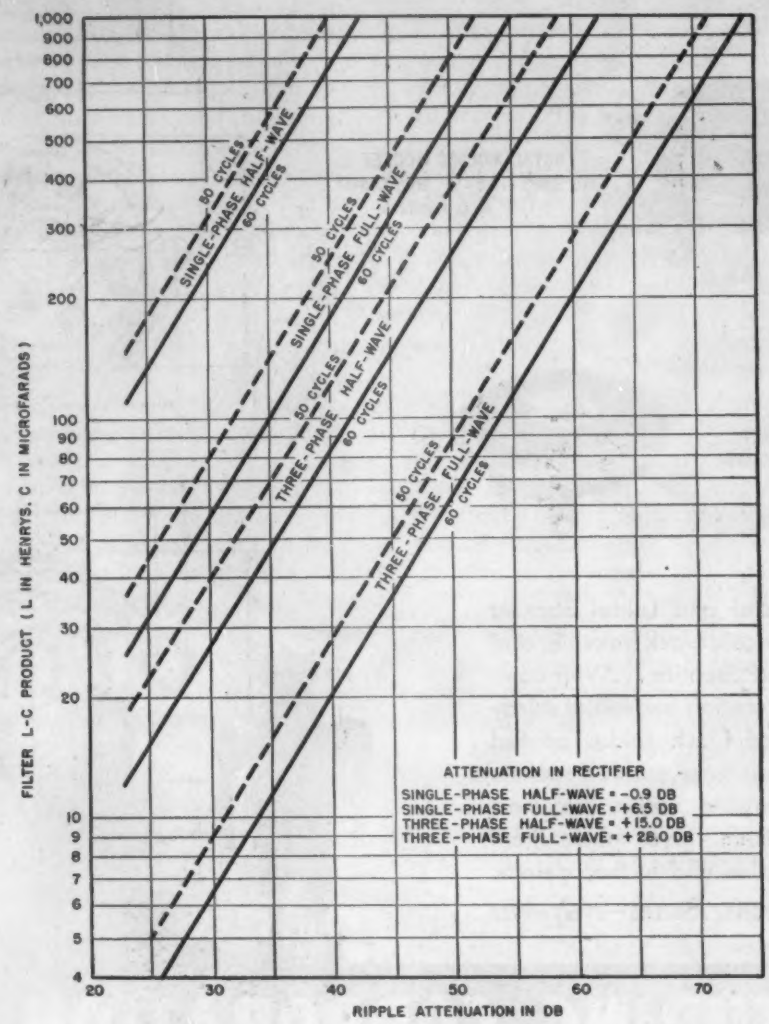
Where choke input is used, output characteristics are readily predetermined. Curves are given for 50 and 60-cycle, half-wave and full-wave, and single and three-phase rectifiers. A rectifier attenuation table is included

By C. K. HOOPER

Power Equipment Engineer
Industrial Electronics Division
Westinghouse Electric Corp.
Baltimore, Md.

WHEN USING choke-input filters, the output ripple of rectifier-type power supplies can be predetermined from the accompanying chart.

It is necessary to know the inductance value, in henrys, and the capacitance, in microfarads, for each filter section. Knowing the product of these two terms, the amount of attenuation in db for each filter section can be read directly on the chart. Curves are given for 50-cycle (dashed lines) and 60-cycle (solid lines) power, for the four types of supplies most often used in industrial equipment.



To obtain the total output ripple in db below the d-c level, the equivalent rectifier attenuation must be added to that of the filter sections.

Practical Example

The following example will illustrate the use of the chart. Assume that a single-phase full-wave rectifier operating from a 60-cycle supply has a two-stage choke-input filter. One of the filters consists of a 2-henry choke and 15-μf capacitor. The other filter consists of a 2-henry choke and 20-μf capacitor.

For the first filter, with an L-C product of $2 \times 15 = 30$, the attenuation is read as 24.5 db. The second filter has an L-C product of $2 \times 20 = 40$ and the attenuation is read as 27 db. From the table the equivalent rectifier attenuation of a single-phase full-wave rectifier is given as + 6.5 db.

The total resulting ripple attenuation is the sum of that of the individual filter sections plus that of the rectifier. In this case, the total is $24.5 + 27 + 6.5 = 58$ db rms below the d-c level.

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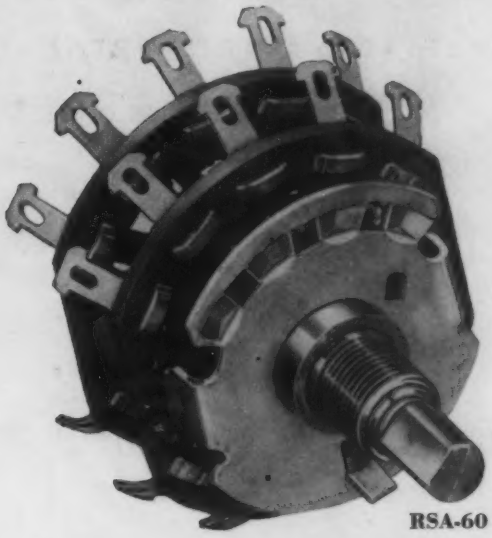

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Ultraviolet Flame Detector 168

Instrument for Intermodulation Measurements

BY GEORGE DANIEL
Western Electric Company
New York, N. Y.

INTERMODULATION measurement makes possible important findings on the subject of distortion not available by other methods. In intermodulation, the interaction of two frequencies is studied, the purpose being to discover the degree to which one frequency is modulated by the other.

More versatile than its predecessor, a new Western Electric equipment for making these measurements consists of a signal generator in which two independent frequencies are produced and combined and an analyzer in which the degree of modulation of the higher frequency by the lower is determined.

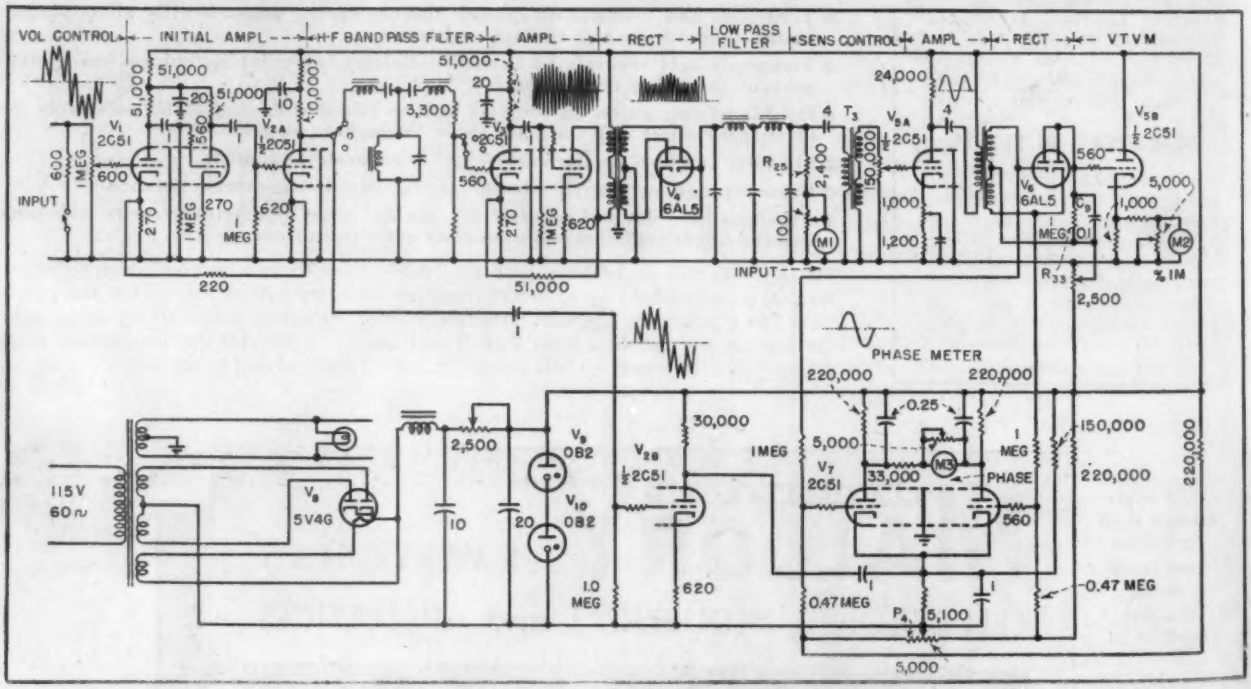
A novel feature of this measuring system is the inclusion of a phase meter which indicates whether compression is occurring on the positive or negative half of the input signal by comparing the phase relationship between the output of the low-pass filter and the low-frequency signal at the input to the analyzer.

Oscillators

In the signal generator two oscillators, each made of a 2C51 miniature dual triode in a resistance—capacitance tuned oscillator circuit, generate the low and high frequencies. Combinations of capacitors provide frequencies of 40, 60, 100, and 150 cycles from the low-frequency oscillator, while similar provision is made for the selection of high frequencies of 1,000, 2,000, 7,000, and 12,000 cycles. Each oscillator circuit includes a 1A type thermistor, or thermally sensitive resistor, which operates on one of the cathodes of each of the 2C51's and, together with a voltage divider, provides negative feed back. The thermistors increase the stability of the oscillator outputs by minimizing variations occurring with changes in gain.

Each oscillator feeds a three-stage amplifier consisting of both halves of a 2C51 and a final push-pull stage. The amplified high frequency is attenuated to 0, 6, 12, or 30 db in relation to the low-frequency output and the two outputs combined in a hybrid coil. The use of a hybrid coil makes possible the combining of the two frequencies with a minimum of intermodulation because each of the amplifiers is separated from the other. At low outputs and for most frequency combinations, this intermodulation is less than 0.2 percent.

In the third stage of the initial amplifier, the plate load is a filter



Schematic of the analyzer section of the intermodulation meter

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THE FRONT COVER

THE CHASSIS shown on this month's cover combines three amplifiers, one modulator, and pulse shaping and clamping circuits, of the Ludwig electronic-hydraulic high speed industrial computer. This unit solves continuously a differential equation involving error, integral of error and derivative of error.

The computer has been developed to solve problems of register in web processing, any manufacturing or converting operation involving a continuous sheet of material, as in printing, cutting, slitting, winding, and rolling. Processing registration accuracies up to and beyond 0.0001 inch on any web can be built into a control which will be fully automatic over a web speed range of ten to one.

The computer on the cover, shown with inventor John W. Ludwig, was adapted to multicolor registration on high-speed fotogravure presses. It holds color register to 0.0001 inch at web speeds ranging from 100 ft per min to 1,000 ft per min. Errors are corrected within 0.15 second. In the case of slow gradual errors, corrective control is thus anticipatory. Comparable accuracies and correction times are engineered into controls governing metal rolling, sheet metal processing, cutting, slitting, roll wind and rewind, fabric and synthetic web processing.

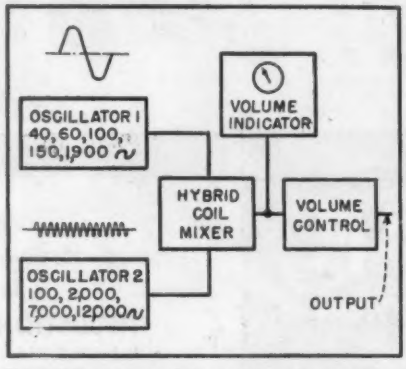
which may be selected by a switch as a band-pass filter of 1,500–2,500 cycles or a high-pass filter of 6,500 cycles. This signal is amplified by both halves of a 2C51 to produce an output of the high-frequency signal modulated by the low-frequency signal to a degree dependent upon the amount of intermodulation in the input signal.

The output of the high-frequency amplifier is rectified and filtered through a low-pass filter with a terminating resistor of 2,400 ohms, R_{25}. The amplitude of the low-frequency voltage impressed on this resistor is relative to the degree of intermodulation in the input signal, while the average current passing through R_{25} indicates the amplitude of the high-frequency input signal.

The low-frequency component from the low-pass filter is impressed upon the primary of transformer T_3, the secondary of which is connected to a variable attenuator which has provision for settings of 5, 15, 50, and 100-percent intermodulation, allowing full-scale intermodulation readings. The output of the attenuator is amplified by one-half of a 2C51 and this output rectified by the 6AL5 full-wave rectifier.

The voltage developed across R_{33} is applied to the grid of the other half of the 2C51 used in the low-frequency amplifier—a space-saving feature made possible by the shielding of the individual sections within the tube—and the triode used as a vtvm in connection with M_2, on which the percentage intermodulation is read directly. In the preceding rectification, the voltage polarity developed is always such as to make the grid negative with respect to ground. The cathode voltage is adjusted by a control on the front panel so that M_2 will read zero percent intermodulation by applying positive d-c voltage to the grid, increasing plate and cathode voltage.

Since the output of the rectifier V_4 is such as to make the grid of the vtvm more negative as the amount of intermodulation increases, the plate current and cathode voltage decrease with intermodulation increase, causing the pointer of M_2 to move.

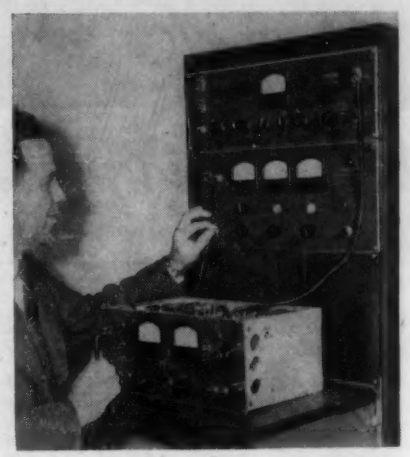


Essential stages of the system for measuring intermodulation distortion

Although the new system will be of value in many fields where audio frequencies are used, it will be of particular importance in the measurement of intermodulation on variable density sound track where intermodulation occurs not only during recording, but within the film itself.

Application

To determine optimum processing and recording techniques, the output of the signal generator is adjusted so as to modulate the light valve about 1.5 db below the clash point, or the point at which the two ribbons of the light valve overlap in the path of the light beam, thereby providing the maximum safe modulation. Recordings are then made at several recorder lamp intensities and the negatives processed for various values of gamma. Positive prints are next made for each negative at several printer light values in a region which past experience has shown to be acceptable.



The signal generator and analyzer mounted on the rack form the two units of the Western Electric intermodulation test set for measuring audio-frequency distortion caused by intermodulation

Each of the several positives is then run on a suitable reproducer and the output fed into the intermodulation analyzer. The print which gives the optimum reading in terms of intermodulation percentage is then used as a guide in making further, more specific tests by

(continued on p 150)

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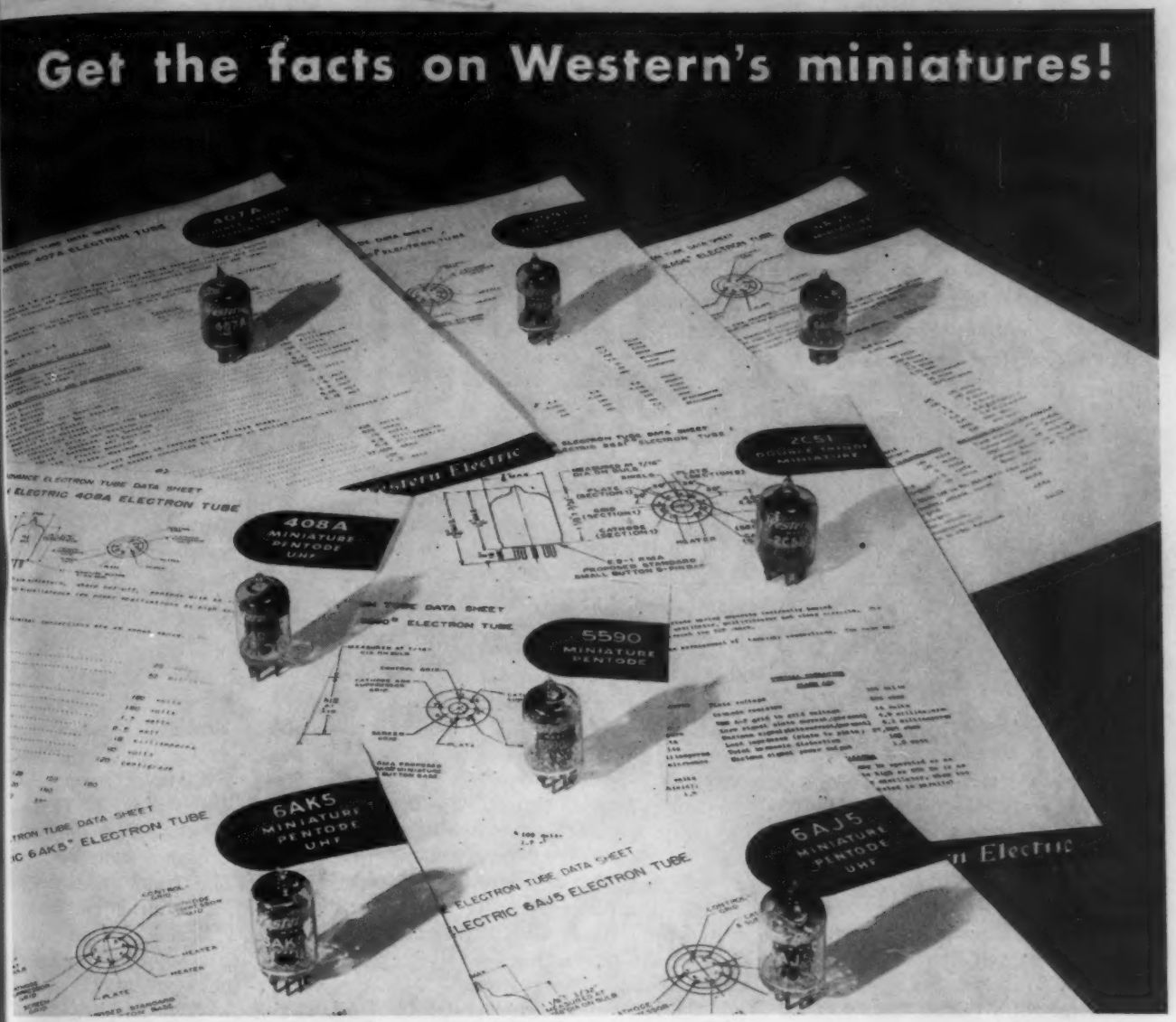

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6AK5	Pentode	6.3	175	180
6AJ5	Pentode	6.3	175	180
5590	Pentode	6.3	150	180
5591	Pentode	6.3	150	180
408A	Pentode	20	50	180
2C51	Twin Triode	6.3	30	300
407A	Twin Triode	20 (parallel) 40 (series)	100 (parallel) 50 (series)	300

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6AK5	5590	408A	407A

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THE ELECTRON ART

Edited by FRANK ROCKETT

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Recording Spectrometer 140
Development and Applications of the Skiatron 174
Measuring R-F Power with a Thermopile 180
Directly Coupled Phase Inverter 188
Survey of New Techniques 190

Theoretical Requirements for Communication Systems

ADDITIONAL LIGHT was shed on new methods for determining effectiveness of communication systems in utilizing frequency spectrum, transmission time, and transmitter power to convey information from point to point in the presence of noise by W. G. Tuller, Project Engineer of Melpar Inc., before 120 members of the Princeton Section of the IRE on January 8 at Princeton University. After philosophizing as to whether communication systems convey information or intelligence, Mr. Tuller presented criteria by which such systems can be evaluated. The concepts, reported below, are extensions of the Hartley Law, which has been recently modified to include the effect of signal-noise ratio (ELECTRONICS, p 72, Jan. 1948).

Elements of Communications

To determine efficiency with which a communication system, the essential feature of which is usually the modulation, utilizes its transmission medium, the fundamental laws of communications need to be known. Knowing these laws, their influence on specific systems can be determined. However, here the interest is limited to the laws themselves.

Consider the simplified communication system of Fig. 1A. Laws governing this system can be deduced most directly by considering its abstract (mathematical) properties. Thus, the transmitter can be considered to map the information signal S from its two-dimensional (time and amplitude) aspect or space to the modulated carrier C in its multidimensional space, with a one-to-one correspondence between S and C. The receiver reconverts C to S. The information occupies a bandwidth F and continues for a time T. The carrier occupies a bandwidth B and (in this discussion) is transmitted for time T. White thermal (completely random) noise N unavoidably enters the system.

If there is any known correlation between parts of the signal of higher probability than between parts of the information that is to be transmitted, it should be removed before modulation; the signal will then have the same characteristic as white noise passed by the same bandwidth. (What is meant by the mathematical concepts of the foregoing statement can be illustrated by a typical example. An operator, in copying telegraphy through strong interference, is able to fill in unintelligible letters by knowing what the words ought to be. He correlates what precedes and follows portions of the signal to find out what the garbled portions are. In this case more letters are transmitted than the probability of the receiving operator's deducing them necessitates. Not all the letters needed to be transmitted in the first place for the operator to have deduced the complete message.) For example: because the amplitudes for the frequency components of speech decrease with increasing frequency, whereas the amplitudes of all the frequency components of noise are equal, pre-emphasis should be used to remove the amplitude-frequency correlation of speech.

At the receiver output, because of the noise, there is a region of uncertainty about the amplitude of the signal as shown in Fig. 1B. The noise N fixes the depth of this region. (The system must be designed to provide a maximum amplitude of the signal so that the signal-noise ratio meets the requirements of whatever service the channel is to be used for.) Therefore only $(1 + S/N)$ discrete amplitudes of signal can be distinguished. (The "one" arises from the fact that, if a line is cut by M intersections, it is divided into $1 + M$ segments, counting the ends as well as the segments between intersections.) The amplitude dimension of the signal is thus broken into a series of discrete levels. The signal is said to be quantized because of the parallel to the quantum theory. Quantization is done at the amplitude intervals that can be just distinguished in the presence of the finite noise.

It is unnecessary to transmit a continuously varying signal. Therefore the quantized signal can be sampled at the fastest rate at which it is expected to exhibit a distinguishable change in amplitude because of its finite bandwidth, as

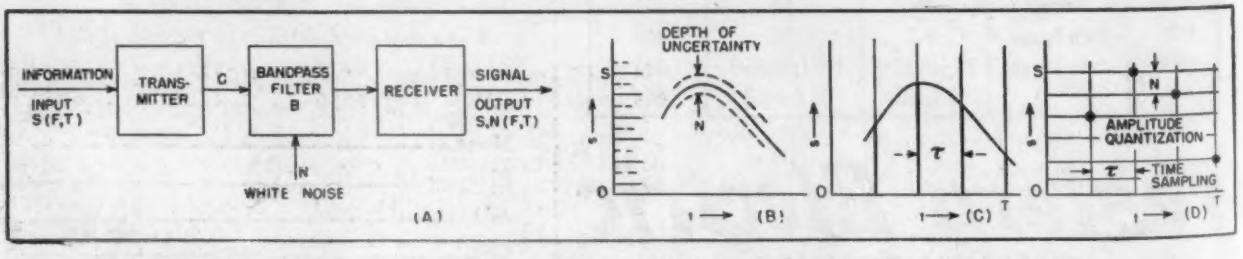

FIG. 1—Basic elements of simple communication system indicate that transmission can be by two-dimensional points

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THE BEAT FREQUENCY GENERATOR

TYPE 140-A

AN IMPORTANT FEATURE

of this instrument is the large dial scale which has been planned for maximum readability and rapid setting—the overall dial scale length from 20 cycles to 5 megacycles exceeds 22 inches. The low frequency scale overlaps the high frequency scale at 30 kc, permitting continuous frequency coverage over the entire audio spectrum without bothersome range switching.

One of the most valuable instruments in the laboratory is a generator of signal voltage. Boonton Radio Engineers in designing the Type 140-A Beat Frequency Generator have provided an instrument of wide frequency coverage, capable of supplying accurate output voltages ranging from several microvolts to 30 volts and having a variety of output impedances from 20 ohms to 1000 ohms.

A 1-inch cathode ray tube has been provided to standardize the low frequency range against the power line frequency and to allow multiples of this frequency to be set with excellent accuracy by means of the cathode ray tube pattern.

An output attenuator having five decimal steps permits accurate setting of voltages as little as 1 millivolt. Engineers making gain or sensitivity measurements will particularly appreciate this feature.

FREQUENCY RANGE: 20 cycles to 5 megacycles in two ranges. Low range: 20 to 30,000 cycles. High range: 30 kc to 5 megacycles.

FREQUENCY CALIBRATION: Accuracy ±2 cycles up to 100 cycles, ±2% above 100 cycles.

STABILITY: About 5 cycles drift below 1000 cycles. On low range, drift becomes negligible percentage with increasing frequency. On high range, drift is 3% or less.

ADJUSTMENT: High and low ranges have individual zero beat adjustments. Low range may be checked against power line frequency with front panel 1-inch cathode ray tube.

OUTPUT POWER AND IMPEDANCES: Rated power output: One watt, available over the low frequency range from output impedances of 20, 50, 200, 500, 1000 ohms, and over both high and low frequency ranges from an output impedance of 1000 ohms.

DISTORTION: 5% or less at 1 watt output, 2% or less for ½ voltage output.

VOLTMETER ACCURACY: ±3% of full scale reading.

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shown in Fig. 1C. Sampling produces T/τ samples in time T at intervals of τ, $\tau = 1/2F$, where F is the highest frequency component in the signal. The result of amplitude quantization and time sampling is a series of signal points as shown in Fig. 1D.

Because all information-bearing signals can be reduced to such points, the series of random points is the most general form of signal. Only the coordinates (time and amplitude) of these points need be considered in communication theory. In practice these coordinates are transmitted in any convenient way such as carrier amplitude modulation, frequency deviation, or binary pulse code. At the receiver the particular modulation process is performed in reverse.

Characteristics of Systems

The foregoing treatment shows that the number of two-dimensional information points is $2FT$, and that each one occurs at random from a set of $(1 + S/N)$ possible points. Therefore, to handle this signal, an area capable of handing $(1 + S/N)^{2FT}$ total signals is required, or the capacity H of the information signal space is

$$H = (2FT) \log (1 + S/N) \quad (1)$$

whereas heretofore the basic communication law has stated that the capacity was proportional to the product of the bandwidth and the time FT.

In a similar manner, the capacity for containing information of the carrier space is $(2BT)$ log $(1 + C/N)$. In designing a communication system, the capacity of the information space is made equal to that of the carrier space, so that $(2FT)$ log $(1 + S/N) = (2BT)$ log $(1 + C/N)$. To simplify the mathematics, assume that both information and carrier signals are well above the noise, so that the equation reduces to

$$(S/N) \gtrsim (C/N)^{B/F} : \text{Case I}$$

where the "less than" is necessary because of the immediately foregoing simplifications. In Case I the transmitter sends more or less than one point for each information point; that is, it maps into a higher or lower order space, as in pulse code modulation in which each information point is transmitted as several pulses of the code group.

If the transmitter sends one point for each point from the information signal, mapping into the same order space, the relation is the familiar

$$(S/N) \gtrsim (B/F)\ (C/N) : \text{Case II}$$

applying to a-m, p-m, and f-m. The characteristics of any communication system can be expressed by one of these two relations.

Examples of Realization

These theoretical considerations can be used to study properties of any method of modulation, or to determine minimum requirements for a given service. For example; if B/F is to be smaller than unity, when transmission occupies less bandwidth than the information, C/N must be large to maintain a useful S/N. Or in general, the capacity of the two portions (information and transmission) of the system are made equal by adjusting the signal-noise ratio to compensate for changes in bandwidth. In Case I the exchange of signal-noise ratio for bandwidth is exponential, in Case II the exchange is simply multiplicative.

To visualize how wideband information can be transmitted in a narrow band, consider a generalized signal that consists of an amplitude-modulated pulse train. The amplitudes of three consecutive pulses of the train are 3, 5, and 7 units, the peak possible amplitude being 10 units. Instead of transmitting these three sharp pulses in rapid sequence, they can be converted, by complex terminal equipment operating along the lines of digital computers, into a single pulse 357 units in amplitude. This pulse can then be transmitted in the same time that the three would have required, and it can be much wider than any one of the original three. The transmitted bandwidth is thus reduced. If the amplitudes of the three original pulses are to be recovered to an accuracy of one part in ten, $S/N = 10$, the C/N will have to be 1,000. Because three information points are transmitted as only one point, this is a Case I system. The transmitted bandwidth would be about a third the information bandwidth.

Unfortunately, in Case II systems, bandwidth can be reduced only by increasing transmission time because, as originally postulated, each information point is transmitted as a single transmission point. The most obvious example of a narrower band Case II system is that based on recording the message and transmitting the record at low speed. This method requires consideration of message duration, the law for which has long been known and need not be reviewed here. In general, Case II systems are best used to improve signal-noise ratio by increasing bandwidth, as is done in frequency modulation. In this instance $(S/N) = \sqrt{3}(C/N)$, the $\sqrt{3}$ arising because a rectangular spectrum is assumed in the derivation, but is not used practically.

Although terminal equipment for such systems is costly, being both more complex and requiring higher transmitter power, it may be justified by the necessity to provide facilities for the growing volume of communication to be handled in the available frequency spectrum.

Recording Spectrometer

QUANTITATIVE ANALYSIS of low-alloy steels can be made quickly with a direct reading spectrometer containing 12 light receivers. The instrument comprises a conventional exciter for producing a high intens-

Industrial materials can be analysed in a minute with this direct-reading

ity spectrum from the metallurgical sample to be analysed, and a grating spectrometer producing a long focal curve. To obtain direct indications of percentages of alloys present, 12 light receivers with in-

(continued on p 174)

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It's easy to install . . . no complicated orienting required.
Nothing else to buy . . . unit almost completely pre-assembled.

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NEW PRODUCTS

Edited by A. A. McKENZIE

New equipment, components, tubes, testing apparatus and products closely allied to the electronics field. A review of catalogs, handbooks, technical bulletins and other manufacturers' literature

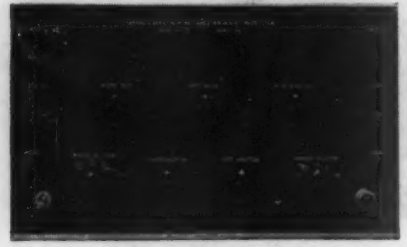
Television Camera (1)

GENERAL ELECTRIC Co., Syracuse, N. Y. The 56-pound television camera is ten inches wide, ten inches high and twenty inches long. Designed primarily for studios, it

is mounted on a mobile dolly and may be operated with fingertip control. Acceptable pictures can be obtained at 50 foot-candles and f/3.5.

Sweep Calibrator (2)

BROWNING LABORATORIES, INC., Winchester, Mass. Model GL-22 sweep calibrator is a pulsed timing marker oscillator designed for use with standard oscilloscopes for the accurate measurement of time intervals on either triggered or recurrent sweeps. Markers available are 0.1, 0.5, 1.0, 10, and 100 microseconds. Operation of the calibrator can be by use of external synchronizing triggers or from its own trigger generator.



Industrial CRO (3)

ALLEN B. DU MONT LABORATORIES, INC., 2 Main Ave., Passaic, N. J. The new type 256-D cathode-ray oscilloscope includes special features for various industrial and research applications. Provision is made for internal calibration of sweep circuits. Accelerating potential of 4,000 volts produces a clear trace. Sweep speeds from 4 to 4,500 microseconds can be selected in 6 ranges, while expanded and delayed portions of the above sweep are also available at speeds of 4, 10, or 25 microseconds. There are other special features.

USING THE NUMBERS

Readers desiring further details concerning any item listed in the New Products department can obtain the information by using the cards furnished as a stiff, colored insert elsewhere in this department.

Place the number (appearing to the right of the heading) of one item in which you are interested in a circle and then fill out the balance of the card according to directions appearing on the colored sheet. Unnumbered items listed at the end should be procured direct from the manufacturer or publisher upon payment of the fee noted.

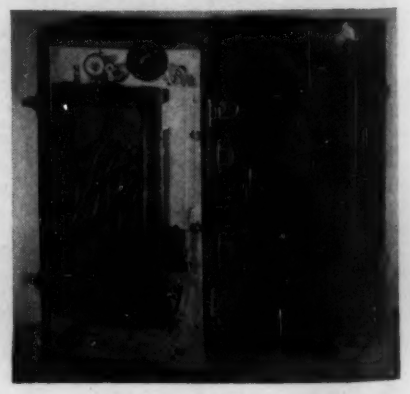
Noise Suppressor Amplifier (4)

FISHER RADIO CORP., 41 East 47th St., New York, N. Y. A new wide-range amplifier that embodies the

Scott dynamic noise suppressor shows only 1 percent distortion at 20 watts output, has less than 0.5 percent intermodulation distortion at 5 watts output, and exhibits uniform response within plus or minus 1 db from 20 to 20,000 cycles. The amplifier is priced at $254.50.

Talking Ads (5)

MAGNECORD, INC., 304 W. 63rd St., Chicago 21, Ill. AudiAd is a magnetic tape recorder that plays back a total of more than 60 seconds of speech or other sound, either continuously or in brief segments, after being tripped by a light-beam



This RAYTHEON Subminiature Tube...

Inside *this* Probe (actual size)...

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This WESTON Instrument, employing the small probe, pictured, provides a stable vacuum tube voltmeter with a range up to 300 megacycles. Combined with this in the one instrument is a volt-ohm-milliammeter and a high impedance electronic volt-ohmmeter.

The handy sized probe permits ready measurement of high frequency potentials in restricted spaces. Its convenience in use and the stability and broad frequency range of the Instrument may be attributed in part to the use of the Type *CK 606 BX* Raytheon Subminiature Tube.

Why WESTON and other manufacturers of high grade electronic equipment use RAYTHEON Subminiature Tubes.

1. **Reduced Product Size . . . Increased Product Salability.** Raytheon filamentary Subminiatures are *flat*. Batteries can be tiny because of extremely low filament drain.
2. **Plug Into Standard Sockets.** All Raytheon Subminiatures can either be soldered in or plugged into readily available sockets.
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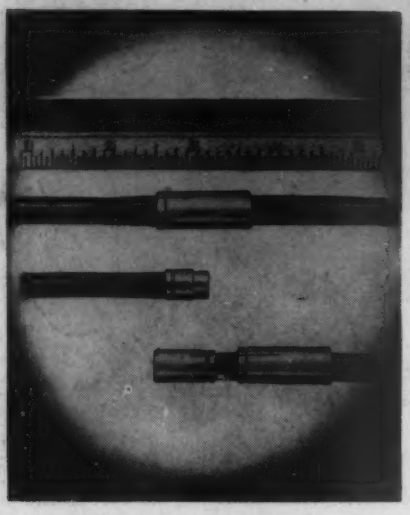
or similar switch. Interchangeable magazines of magnetic tape can be recorded with advertising copy or the individual user can make his own recordings on the spot.

High Altitude Tube (6)

AMPEREX ELECTRONIC CORP., 25 Washington St., Brooklyn, N. Y. Developed for the Army Air Forces for use at high altitudes is a half-wave rectifier rated at 14,000 peak inverse volts. It delivers an average plate current of 125 ma and a peak current of 750 ma. The special tube-socket combination will handle voltages as high as 35,000 volts peak. Base of the tube is tapered and ground to fit the socket like a glass bottle stopper.

Miniature Connectors (7)

H. H. BUGGIE & CO., 2145 Madison Ave., Toledo 1, Ohio, manufacture a connector with an overall diam-



eter of 23/64 inch. It has a voltage rating of 500 volts peak with a low loss. The unit is solderless and requires minimum cable preparation.

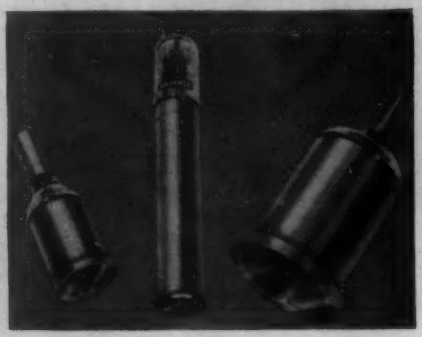
Resistance-Tuned Oscillator (8)

HEWLETT-PACKARD CO., 395 Page Mill Road, Palo Alto, Cal. Model 650A resistance-tuned oscillator is a wide-band precision instrument which provides output flat within

1 db from 10 cycles to 10 mc, and a voltage range of 0.00003 to 3 volts. Output impedance is 600 ohms or 6 ohms with output voltage divider.

G-M Counter Tubes (9)

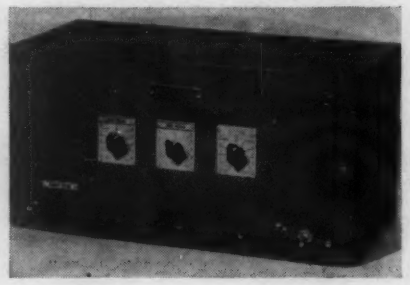
AMPEREX ELECTRONIC CORP., 25 Washington St., Brooklyn 1, N. Y. Physically redesigned for standard-



ized production the new series of Geiger tubes includes counter tubes for beta, gamma, and x-rays. Featured herein are direct bonds between mica and metal and mica and glass.

Multiple Power Supply (10)

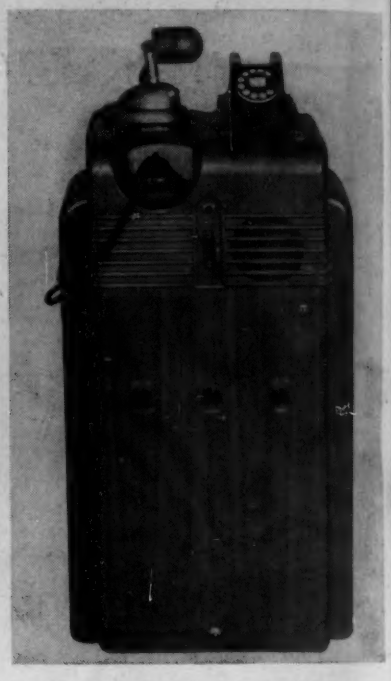
KEPCO LABORATORIES, INC., 142–45 Roosevelt Ave., Flushing, N. Y. Model 103 multiple power supply was developed to supply four commonly used voltages from a single compact unit. The power supply contains two continuously variable



B supplies delivering from 0 to 300 volts at currents up to 120 milliamperes, one variable C supply delivering from − 50 to + 50 v at 5 ma, and one heater supply delivering 6.3 volts at 5 amperes.

Group Telephone (11)

JORDANOFF AVIATION CORP., 595 Madison Ave., New York, N. Y. has begun limited production of the



Jordaphone, a device which permits group telephone conversations without individual headsets. It consists of a regulation telephone, console cabinet and microphone. Impulses in the receiver are picked up by a coil in the console and amplified. In transmitting, the talker's voice is heard without amplification. A built-in receptacle cuts out all outside noises from both ends of the handset.

Well Sounder (12)

KEYSTONE DEVELOPMENT CORP., 2813 Westheimer Road, Houston, Texas. Sonolog is an instrument for the acoustic determination of the fluid level in the annular space between the casing and the tubing of an oil well. A small chamber attached to a casing at the surface

(continued on page 198)

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3. *High arc resistance*
4. *Stability over wide humidity and temperature changes*
5. *Resistance to high temperatures*
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7. *Mechanical strength*
8. *Metal inserts molded in place*
9. *Minimum service expense*
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NEWS OF THE INDUSTRY

Edited by JOHN MARKUS

New WWV time signal schedule; Marine Corps starts electronic warfare training; reviews of 11 new technical books

Television Receiver Symposium

EIGHT technical papers dealing with television receivers are scheduled for presentation Feb. 28, 1948 at an all-day symposium sponsored by the IRE New York Section, in the main auditorium of the Engineering Societies Building in New York City.

The program is as follows:

10:00 a.m.—Television Receiving Antennas, by Andrew Alford of Boston, Mass.
10:30 a.m.—Television Antenna and R-F Distribution Systems for Apartment Houses, by Heinz Kaliman of New York City.
11:00 a.m.—Automatic Frequency Control of Television Sweep Circuits, by E. L. Clark of RCA Victor.
11:30 a.m.—Standards for Testing Television Receivers, by D. G. Fink of ELECTRONICS.
2:00 p.m.—Intermediate Frequencies for Television Receivers, by Paul F. G. Holst of Crosley Division, AVCO Mfg. Co.
2:30 p.m.—I-F Amplifiers for Intercarrier System of Sound Reception, by S. W. Seeley of RCA Laboratories.
3:00 p.m.—Television Tuners, by Alarico Valdettaro of Bloomington, Ind.
3:30 p.m.—Standardization of Transient Response of Television Transmitters and Receivers, by G. L. Fredendall of RCA Laboratories.

Moderator for the morning session is Arthur Loughren of Hazeltine Electronics Corp., and moderator for the afternoon session is Murray Crosby of Paul Godley Co.

Eta Kappa Nu Honors Young Electrical Engineers

ACTIVITIES in the field of electronics appear frequently in the biographical sketches of the six Eta Kappa Nu Recognition Award winners and the fifteen winners of honorable mention. Suspended during war years because security regulations prevented divulging the work of many candidates, the resumption of awards this year cites one outstanding young engineer and a number of honorable mentions for each of the years 1942 through 1947.

Achievements considered in making the selections stress cultural development and contributions to community, state, and national welfare as well as professional achievement. The name of each award winner is engraved on a bronze bowl displayed in AIEE headquarters in New York City and each winner is given a miniature replica of the bowl. Honorable mention winners received certificates.

Winners, with colleges from which they graduated and present business affiliations, are as follows:

RECOGNITION AWARDS

1942 John R. Pierce; California Institute of Technology, 1933; Bell Telephone Laboratories, Inc., New York, N. Y.

1943 Nathan I. Hall; West Virginia University; Hughes Aircraft Company, Culver City, Calif.

1944 Richard W. Porter; University of Kansas, 1934; General Electric Co., Schenectady, N. Y.

1945 James M. Wallace; University of Pittsburgh, 1935; Westinghouse Electric Corporation, Pittsburgh, Pa.

1946 Everard M. Williams; Yale University, 1936; Carnegie Institute of Technology, Pittsburgh, Pa.

1947 Richard R. Hough; Princeton University, 1939; Bell Telephone Laboratories, Inc., Whippany, N. J.

HONORABLE MENTIONS

1942 Gilbert D. McCann, Jr.; California Institute of Technology, 1934; California Institute of Technology, Pasadena, Calif.

David B. Smith; Massachusetts Institute of Technology, 1933; Philco Corporation, Philadelphia, Pa.

1943 Armig G. Kandoian; Harvard University, 1934; International Telephone and Telegraph Company, New York, N. Y.

James W. McRae; University of British Columbia, 1933; Bell Telephone Laboratories, Inc., New York, N. Y.

1944 William E. Ingerson; Hardin-Simmons University; Bell Telephone Laboratories, Inc., Murray Hill, N. J.

Ernst H. Krause; University of Wisconsin, 1934; Naval Research Laboratory, Washington, D. C.

Donald W. Pugsley; University of Utah, 1935; General Electric Company, Bridgeport, Conn.

1945 Wallace A. Depp; University of Illinois, 1936; Bell Telephone Laboratories, Inc., New York, N. Y.

Jack A. Morton; Wayne University, 1935; Bell Telephone Laboratories, Inc., New York, N. Y.

Edgar A. Post; University of Illinois, 1936; United Air Lines, Chicago, Ill.

1946 Benjamin B. Bauer; University of Cincinnati, 1937; Shure Brothers, Inc., Chicago, Ill.

Albert C. Hall; Agricultural and Mechanical College of Texas, 1936; Massachusetts Institute of Technology, Cambridge, Mass.

Donald L. Waidelich; Lehigh University, 1936; University of Missouri, Columbia, Mo.

1947 Marvin Camras; Illinois Institute of Technology, 1940; Armour Research Institute, Chicago, Ill.

Jerome B. Wiesner; University of Michigan, 1937; Massachusetts Institute of Technology, Cambridge, Mass.

AIEE Tube Conference

NEED for tubes having longer life and closer tolerances, for use in electronic instruments, has resulted in an AIEE tube conference to be held March 29 and 30 at the Benjamin Franklin Hotel in Philadelphia. Instrument and tube manufacturers, as well as engineers from industrial, commercial, and

1942
J. R. Pierce

1943
N. I. Hall

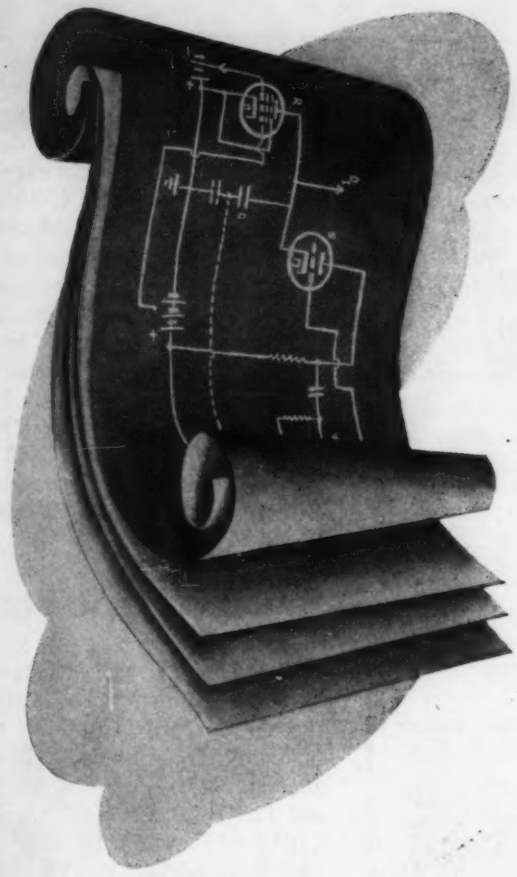
1944
R. W. Porter

1945
J. M. Wallace

1946
E. M. Williams

1947
R. R. Hough

Specialized Knowledge and Equipment for UHF DESIGN



● The phenomena encountered in the UHF field are in many cases so decidedly different from those true of lower frequencies that many manufacturers find themselves in urgent need of specialized UHF knowledge, in order to develop equipment that will handle certain specific conditions.

● Since we are specialists in UHF engineering, we are equipped not only to render technical advice, but also to follow through in the actual production of equipment in our shops.

● If you are contemplating a new product, or have a problem involving ultra high frequency with present production, our specialized knowledge should be invaluable for quick, accurate, low unit cost. There is no cost or obligation involved in talking this over.

U H F

Lavoie Laboratories

RADIO ENGINEERS AND MANUFACTURERS
MORGANVILLE, N. J.

Specialists in the Development and Manufacture of UHF Equipment

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university laboratories will convene. AIEE members will be admitted free, and the fee for nonmembers is $2.00. Requests for invitations should be addressed to C. C. Wilson, AIEE Headquarters, 33 W. 39th St., New York 18, N. Y.

Chicago Scientific Center

THE WESTERN Society of Engineers has signed an agreement with the John Crerar Library in Chicago, leasing three floors in the Taylor building, which adjoins the Library, and establishing a science and technical center for the use of professional persons, students, and others interested in the advancement of science. Included in the center is an auditorium seating 300.

The Western Society's 20,000-book collection is being coordinated with the 700,000-volume Crerar Library, largest free public library in the world devoted exclusively to science and technology.

Development of the new science center will cost the engineering society about $100,000.

MEETINGS

FEB. 28: IRE Television Receiver Symposium, sponsored by New York Section; main auditorium, Engineering Societies Bldg., technical papers all day, starting at 10:00 a.m.

MARCH 22-24: Chicago Technical Conference, Stevens Hotel; meetings and exhibits; sponsored by 51 societies, including IRE, SMPE, and AIEE.

MARCH 22-25: IRE Convention and Radio Engineering Show, Hotel Commodore and Grand Central Palace, New York City.

MARCH 29-30: AIEE conference on electron tubes for instrumentation and industry, Benjamin Franklin Hotel, Philadelphia, Pa.

APRIL 1-3: AIEE Great Lakes District Meeting, Des Moines, Iowa.

APRIL 7-9; Midwest Power Conference, Sheraton Hotel, Chicago, Illinois. Three papers on supervisory control and telemetering at 2 p.m. April 9.

APRIL 17: IRE Engineering Conference, Chicago Section, Illinois Institute of Technology, Chicago.

APRIL 24: Spring Technical Conference of IRE Cincinnati Section, featuring television papers, at Engineering Society Headquarters.

APRIL 26-28: IRE-RMA spring meeting on transmitters, Syracuse Hotel, Syracuse, N. Y.

APRIL 28-30: AIEE North Eastern District Meeting, New Haven, Conn.

MAY 3-5: URSI-IRE joint meeting, Washington, D. C.

MAY 9-14: 1948 Radio Parts Show, Hotel Stevens, Chicago.

MAY 11-16: Engineering Progress Show, Franklin Institute, Philadelphia, Pa.: exhibits and two evening lectures.

JUNE 21-25: AIEE Summer General Meeting, Mexico City, Mexico.

AUG. 24-27: AIEE Pacific General Meeting, Spokane, Wash.

SEPT. 13-17: Third Instrument Conference and Exhibit, Convention Hall, Philadelphia, Pa.

SEPT. 27-Oct. 2: Third National Plastics Exposition, Grand Central Palace, New York City.

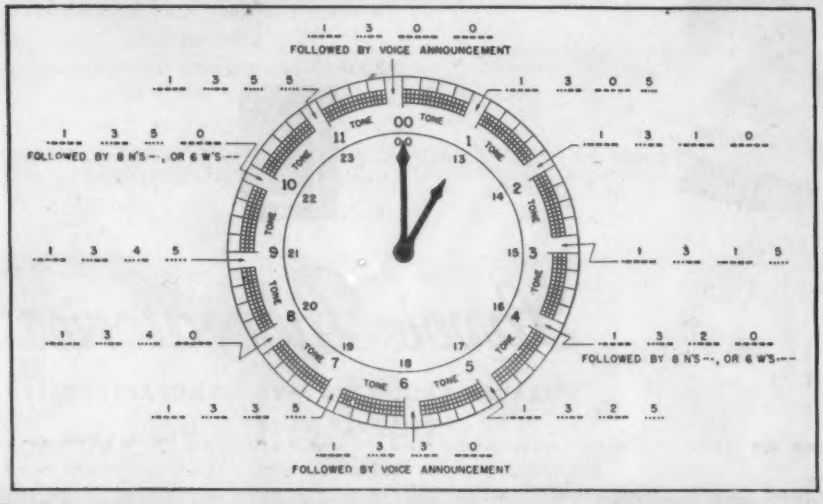
SEPT. 30-Oct. 2: Pacific Electronic Exhibition and IRE west coast Annual Convention, Biltmore Hotel, Los Angeles, Calif.

OCT. 5-7: AIEE Middle Eastern District Meeting, Washington, D. C.

OCT. 11-12: FM Association Second Annual Convention, Sheraton Hotel, Chicago.

New WWV Schedules

EFFECTIVE Jan. 30, 1948, time announcements from radio station WWV of the National Bureau of Standards were advanced one minute with respect to the former announcement scheme (see WWV Schedules, ELECTRONICS, p 87, May 1947). With the new system the audio frequencies are interrupted at precisely one minute before each hour and at each succeeding five-minute period, and are resumed precisely on the hour and each five minutes thereafter. The time announcement, in International Morse Code, refers to the end of the announcement interval (the instant when the audio tone frequencies are resumed), as indicated by the accompanying clock-face diagram.



Example illustrating new schedule of time announcements by station WWV. Hour illustrated is 1 to 2 p. m., or 1300 to 1400 in 24-hour time for Eastern Standard Time

These time signals are now broadcast continuously day and night on all of the eight carrier frequencies in use: 2.5, 5, 10, 15, 20, 25, 30, and 35 mc. A 440-cycle audio tone is transmitted on 2.5, 5, and 30 mc along with pulses at intervals of precisely one second. Both 440 and 4,000 cycle tones are transmitted on 10, 15, 20, and 25 mc along with the time ticks. Further details of WWV broadcast services are given in bulletin LC886, available on request from the National Bureau of Standards, Washington 25, D. C.

Other Time Signal Services

The Naval Observatory, U. S. Navy Department, broadcasts time signals at regular intervals on the following frequencies: NSS (Annapolis, Md.)—122, 4,390, 9,425, and 12,630 kc; NPG (Mare Island, Calif.)—115, 9,255, 12,540 kc; NPM (Pearl Harbor, Hawaii)—16.68, 56, 4,525, 9,050, 13,575, 17,370 kc; NBA (Balboa, Canal Zone)—148, 5,005, 11,080 kc. Detailed information

(continued on p 246)

SIX SOLUTIONS TO YOUR D-C POWER PROBLEMS

Federal Selenium Rectifier Equipments

HERE'S FEDERAL'S line of standard D-C Power Supplies which offer you a convenient, economical and always *dependable* source of direct current for a wide range of industrial and laboratory applications.

These attractively styled, compact and efficient units are completely self contained —ready to connect to your a-c power supply —ready to supply d-c power wherever and whenever you want it. Because they are powered by Federal's long-life Selenium Rectifiers, their service life is practically unlimited—with no expendable parts which require frequent replacement. These equipments are conservatively rated, using the new heavy-duty stacks which assure a wide margin of safety to withstand momentary heavy overloads.

For complete information on these new d-c power supplies, write to Federal today —Dept. E 313.

Available for *IMMEDIATE DELIVERY*

1	**FTR 3300-DS**	D-C Output—2-32 volts, 50 amperes A-C Input—115 volts, 1-phase, 60 cycles
2	**FTR 3339-BS**	D-C Output—6-24 volts, 18 amperes A-C Input—115/230 volts, 1-phase, 50/60 cycles
3	**FTR 3128-BS**	D-C Output—22-30 volts, 10 amperes (filtered and regulated) A-C Input—115 volts, 1-phase, 60 cycles
4	**FTR 3341-AS**	D-C Output—28 volts, 5 amperes A-C Input—115 volts, 1-phase, 50/60 cycles
5	**FTR 3246-BS**	D-C Output—6 volts, 10 amperes (filtered) A-C Input—115 volts, 1-phase, 60 cycles
6	**FTR 1342-AS**	D-C Output—6 volts, 4 amperes (3 cells 6-3 amperes) A-C Input—115 volts, 1-phase, 50/60 cycles

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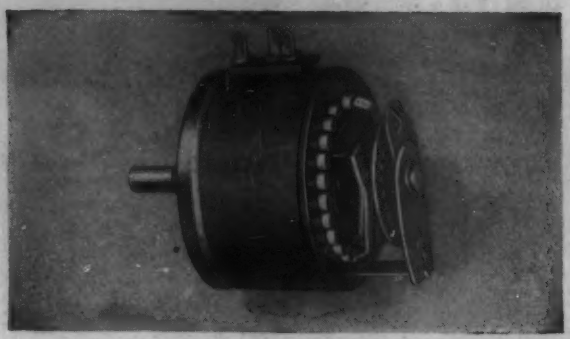
Shallcross
ATTENUATORS

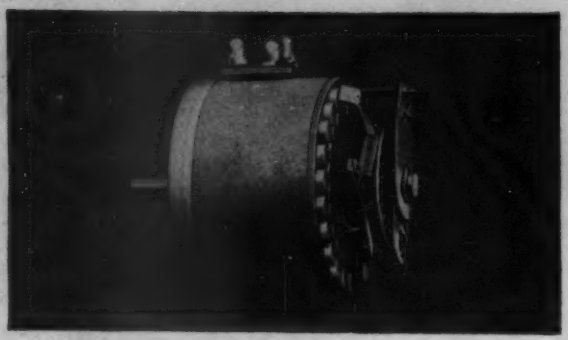


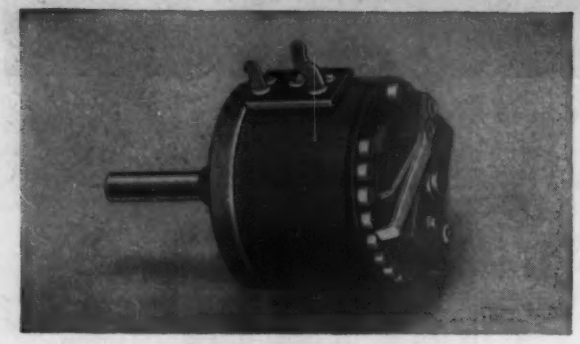
BRIDGED 'T' ATTENUATOR
Type 410-4B1

10 steps, 4 db/step. Linear attenuation with detent. 2⅛" diameter, 2⅛" depth.

BRIDGED 'T' ATTENUATOR
Type 420-2B2

20 steps, 2 db/step. Linear attenuation with off position and detent. 2⅛" diameter, 2⅛" depth.





POTENTIOMETER
Type C720-2A3

20 steps, 2 db/step, tapered on last three steps to off, composition resistors. 1¾" diameter, 1¾" depth.

These Shallcross Features Mean Better Performance—Better Value!

Off position attenuation well in excess of 100 db.

25% to 50% fewer soldered joints.

Noise level ratings that are factual. (130 db. or more below zero level.)

Non-inductive Shallcross precision resistors used throughout assure flat attenuation to and beyond 30 kc.

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SHALLCROSS ATTENUATORS

Shallcross variable attenuators have proved their remarkable quietness and serviceability in dozens of applications for leading users in all parts of the world. Such important details as the use of spring-temper silver alloy wiper arms, silver alloy collector rings and contacts, non-inductive precision resistors, and sturdy, substantial mounting plates have made possible the high standard of performance attributed to Shallcross.

Standard types include ladder and bridged T mixer controls, bridged T and straight T master gain controls and V.U. meter multipliers, wirewound and composition potentiometers for grid control. Cueing attenuators, and fixed pads, both composition and wirewound, in all circuit configurations are also available.

Write for Catalog and Attenuator Specification Sheet

SHALLCROSS MANUFACTURING COMPANY
Department E-38, Collingdale, Pa.

(continued from p 136)

the same method, with printer light values and values of gamma of the negatives only a small amount greater or smaller than those previously found most satisfactory.

High-Frequency Crystal Voltmeter

By B. F. Tyson
Hazeltine Electronics Corporation
Little Neck, N. Y.

A CRYSTAL voltmeter is useful in measuring the gain and response characteristics of the r-f and i-f circuits in f-m and television receivers. Such an instrument is physically small, and when built in probe form can be easily connected to the point of measurement. Inherently, it has high sensitivity and when used with a 10-microampere meter will indicate r-f voltages as low as 0.05 volt.

The voltmeter described here uses a type 1N28 crystal rectifier connected as shown in the circuit diagram of Fig. 1. Other crystals such as types 1N21 or 1N25 can also be used. On the input side, load resistor R_1 and a ceramic d-c blocking capacitor C_1 are built into the probe. On the output side, the r-f components of the rectified current are bypassed to ground through a button mica capacitor C_2 and the direct current to the microammeter is filtered by resistor R_2 and a button mica capacitor C_3.

The physical arrangement of the various parts is shown in the cross-section assembly view of Fig. 2. The smaller diameter half of the probe has the ground and high potential input tabs and contains the blocking capacitor and load resistor. The shielded microammeter lead is brought out of the other half which houses the button-type bypass and filter capacitors and the filter resistor. Note that the large end of cylinder *B* is made to slide fit into cylinder *A* and a clip from

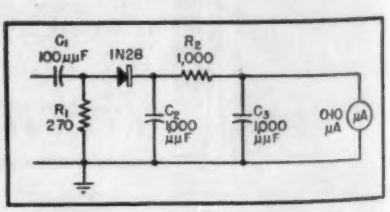
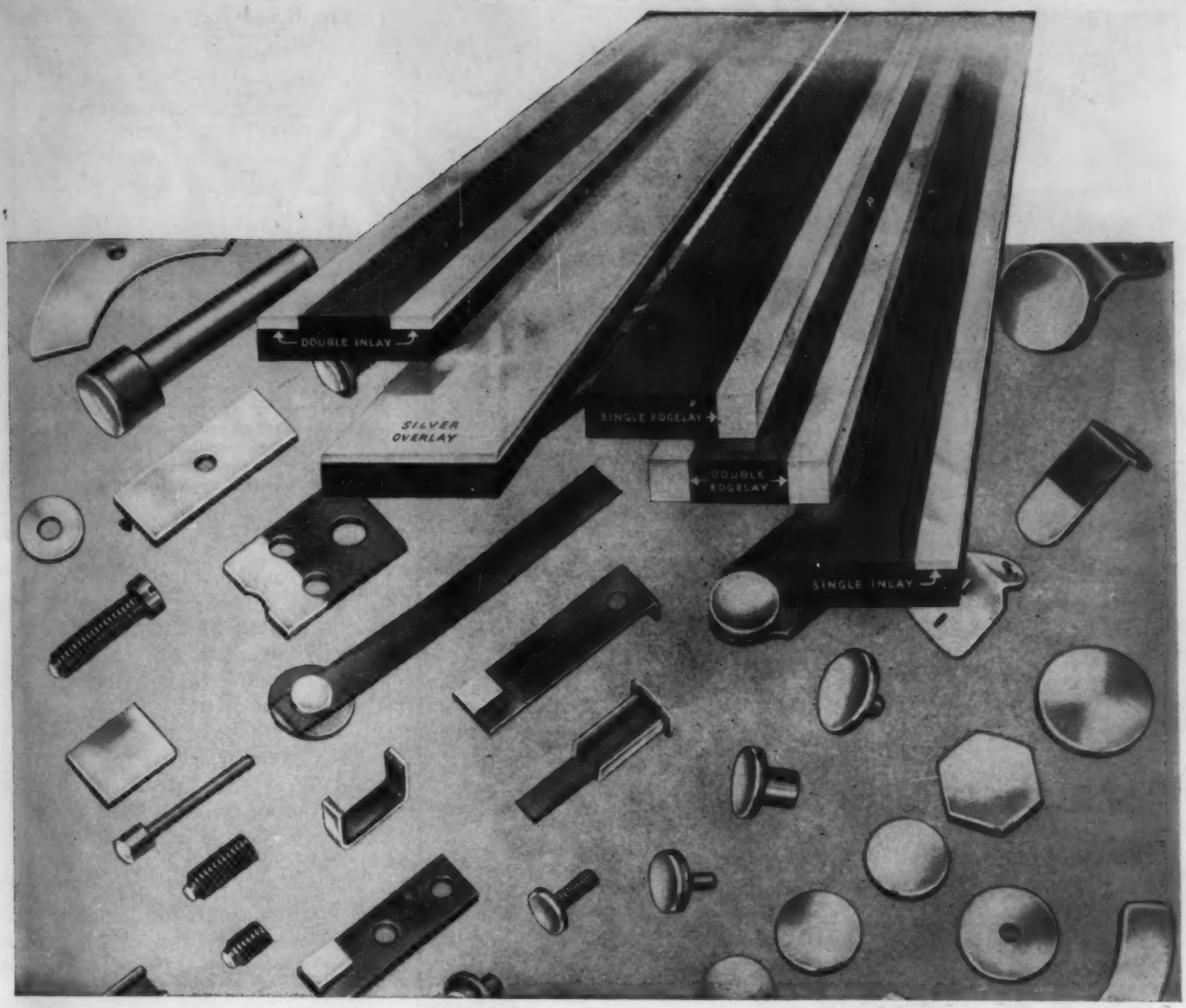


FIG. 1—Circuit diagram of crystal voltmeter



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General Plate Laminated silver metals, for your own fabrication, are available with silver bonded to base metal in the following stock . . . overlay, single or double inlay and single or double edgelay. General Plate contacts and fabricated parts are made to customers specifications. Laminated contact buttons, rivets and screw type contacts are also available. Advantages include — long contact life, greater strength, easier fabrication, and easier soldering, brazing or spot welding.

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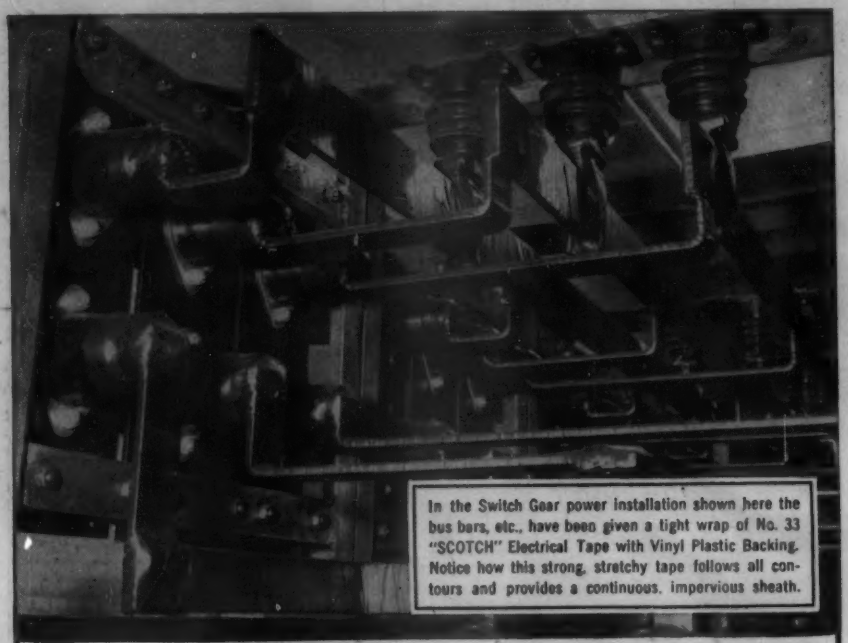

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No. 33 "SCOTCH" Electrical TAPE will not soften or crack even when exposed to oil, acids, alkalies. Superior outdoor aging qualities prevent cracking and checking.

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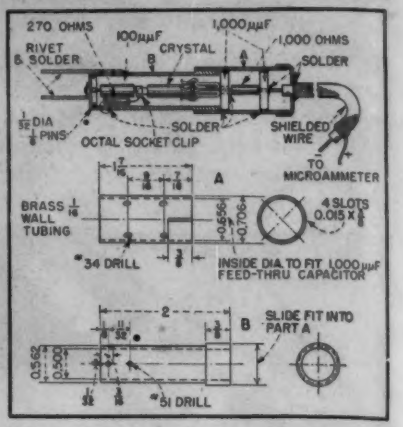

FIG. 2—Crystal probe assembly consists of two cylinders machined so the end of one slides inside the other for rapid replacement of crystal cartridge

an octal socket is soldered to the end of the 100-$\mu\mu$f Ceramicon capacitor to receive the contact of the crystal. The larger, probe end of the crystal is held firmly by a finger contactor. Thus, the entire probe is separable near its center for easy insertion of the crystal cartridge.

Fig. 3 is a typical calibration curve of the crystal voltmeter using a 1N28 crystal. Measured characteristics of several 1N28 crystals indicate that their sensitivities are in the order of 700 to 1,200 microamperes per volt squared and that they have square-low input-output characteristics only for inputs up to approximately 0.1 volt. The compact construction of the probe, minimizes lead inductances and stray capacitances, and the low value of load resistance, 270 ohms, serve to maintain an input-output characteristic substantially independent of frequency from 50 mc to at least 250 mc. At frequencies below 50 mc, the response falls off gradually.

The crystal voltmeter has been checked for susceptibility to burnout. Peak surges of 500 volts d-c or 130 volts, 60-cycle a-c have shown no effect on the calibration. Likewise, it has been determined that the crystal can withstand r-f voltages to produce approximately 1 ma of direct current, without effect on calibration. Higher r-f voltages, or mechanical shocks may, of course, cause a change in calibration or permanent damage.

The crystal voltmeter is intended for observation of r-f voltage across low impedances such as the output terminals of a signal generator or

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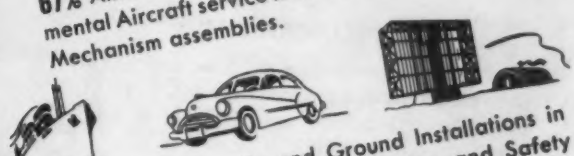

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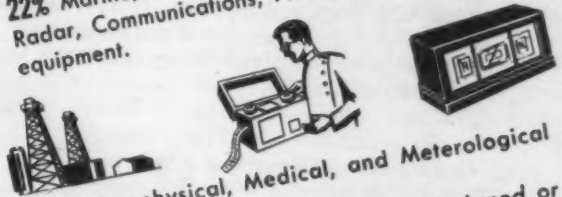

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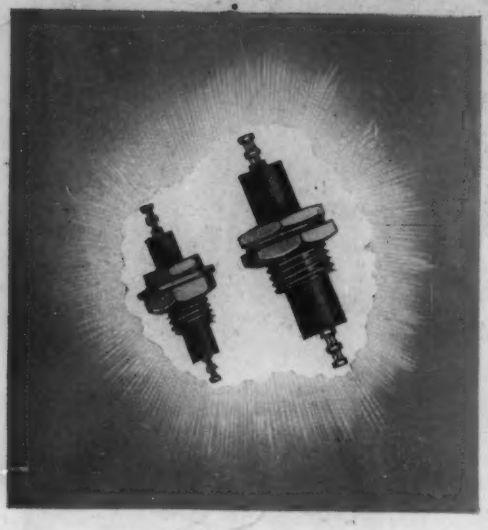
Feeding an R. F. potential through the wall of a cavity oscillator presented many difficulties. Not only was space at a premium, but extreme changes in humidity, temperature and other service conditions had to be met.



THE ANSWER

C.T.C. 1795B Insulated Feed-Thru Terminals fulfilled every requirement. Design-features like these show you why: *Rugged construction that withstands loosening under vibration or shock . . . approved phenolic insulating material, JAN type LTS-E-4 . . . brass bushings, cadmium plated . . . brass thru-terminals, silver plated for easy soldering.*

SPECIFICATIONS

The 1795B mounts in a ¼" hole, and has an over-all length of approximately ⅞". C.T.C. Feed-Thru Terminals are available in additional sizes. The 1795A is similar to the 1795B, but with an over-all length of 1". Also similar in design and function are X1771A and X1771B, but larger in size and mounting in a ⅜" hole. Breakdown voltages, at 60 cycles R.M.S., are:

1795A . . . 3800V X1771A . . . 8200V
1795B . . . 3200V X1771B . . . 6000V

Catalog No. 200 contains details of C.T.C. standard electric and electronic components, together with full information on our custom-engineering service. Write for it today.

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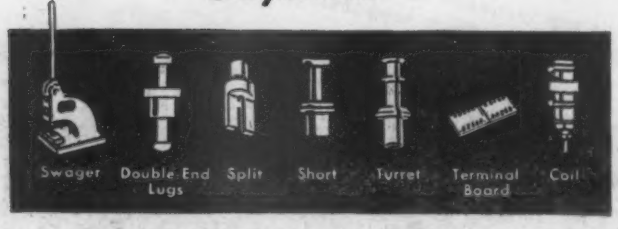

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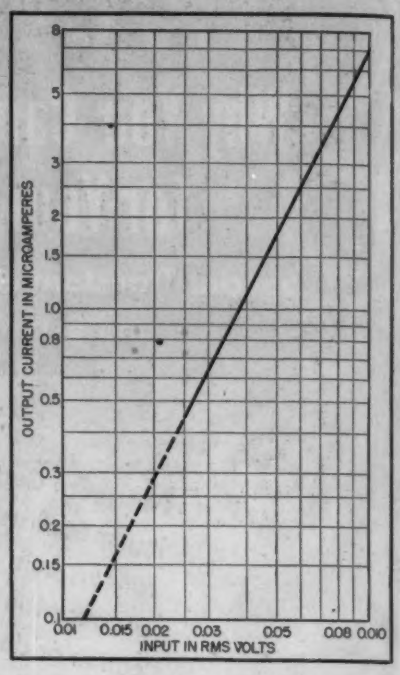


FIG. 3—Typical calibration curve of the crystal voltmeter using a 1N28 crystal

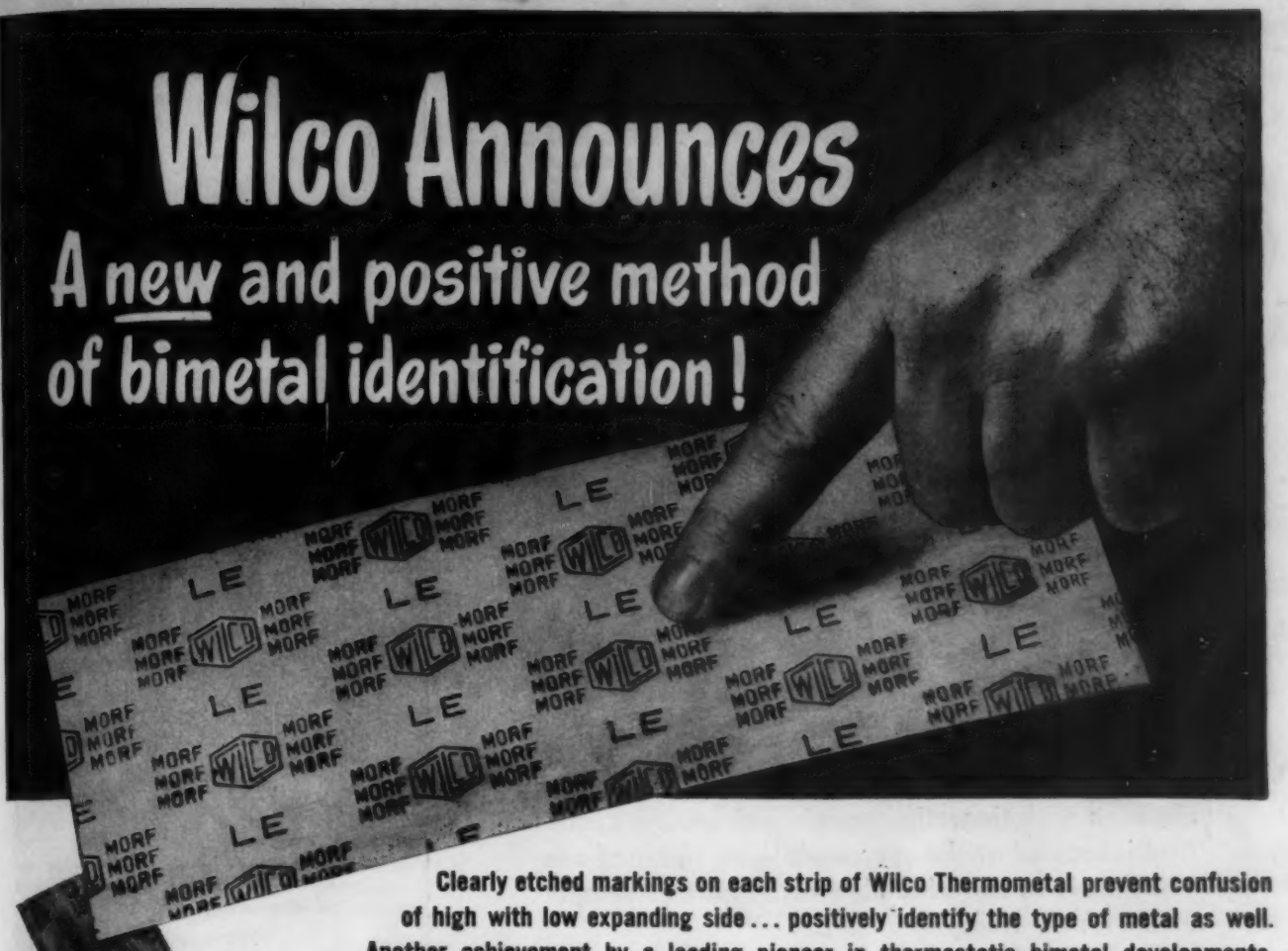
a low-resistance plate load of an amplifier tube. Care should be exercised in connecting the probe for high radio-frequency measurements to avoid excessive lead length and the addition of stray capacitance. When making measurements at low frequencies, say below 50 mc, it should be remembered that the 100-$\mu\mu$f d-c blocking capacitor has appreciable series reactance. It will be observed that the action of the microameter needle is somewhat sluggish due to damping by the crystal resistance. A short time should therefore be allowed for the needle to come to rest before reading the meter.

X-Ray Thickness Gage

GAGING without physical contact with the material under test, and access to areas never before gaged, are features of a new x-ray technique that consists of irradiating the material and measuring the drop in intensity through that material. Designed by Westinghouse engineer W. N. Lundahl for measuring the thickness of cold-rolled steel sheet and cold-rolled copper, the instrument should also prove applicable for use on hot materials like metal and glass sheet, and fragile materials like foil and paper. Readings are unaffected by

Wilco Announces

A new and positive method of bimetal identification!



Clearly etched markings on each strip of Wilco Thermometal prevent confusion of high with low expanding side... positively identify the type of metal as well. Another achievement by a leading pioneer in thermostatic bimetal developments.

LOOK at this strip of WILCO "Morflex."

Its clearly etched characters instantly identify the *low expanding side* of the thermometal. For only the low expanding side shows these markings. (The high expanding side is left unmarked.)

STUDY this thermometal strip more closely, and you will note a second safeguard against confusing it with the high expanding side . . . the frequent repetition of "LE", signifying low expansion.

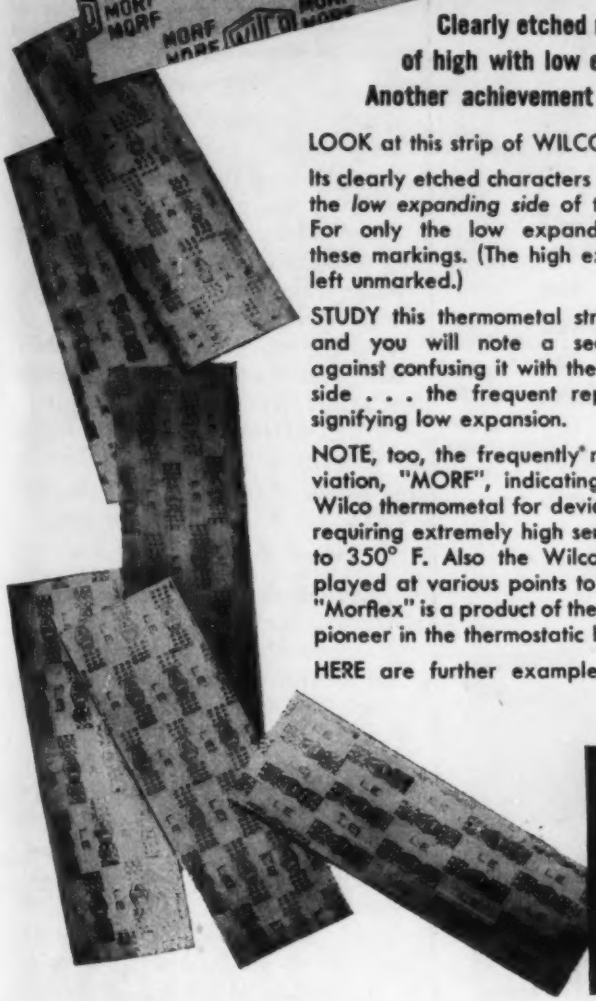
NOTE, too, the frequently repeated abbreviation, "MORF", indicating "Morflex", the Wilco thermometal for devices or instruments requiring extremely high sensitivity from 50° to 350° F. Also the Wilco trademark displayed at various points to remind you that "Morflex" is a product of the H. A. Wilson Co., pioneer in the thermostatic bimetal field.

HERE are further examples that show the consistency with which Wilco carries this clear-cut method of identification throughout the entire line of 29 Wilco Thermometals, precluding any possibility of mistaking one type for another.

Another Wilco pioneering achievement

The H. A. Wilson Company is an American pioneer in the design and development of thermostatic bimetals. WILCO supplies these materials as sheet or strip, in partly or completely fabricated form, and as parts of assemblies for thousands of applications. All temperature ranges, deflection rates and electrical resistivities.

Now Wilco—which for 34 years has *majored* in the development and widespread application of thermostatic bimetals—pioneers again with an etching process that will help to make these Wilco products more than ever *precision products*.



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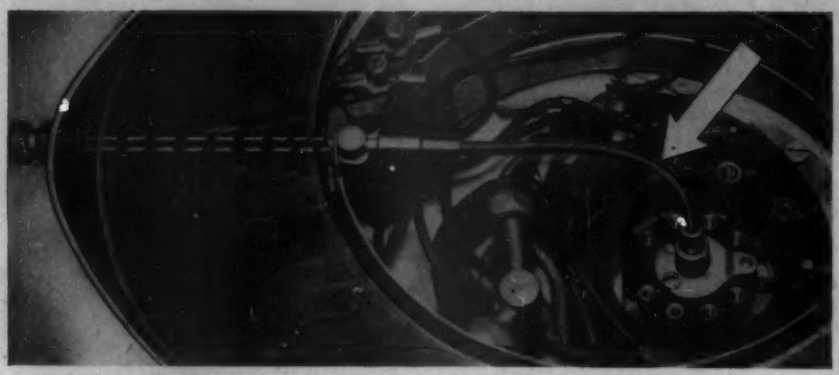

WHEN you design equipment with variable elements you naturally want to provide those elements with fingertip control. This means, control that is located *at* the operator's fingertips, and control that is so smooth and effortless it can be operated *with* the fingertips.

With S.S.White flexible shafts of the type specially designed for this service, you can satisfy both requirements. A typical example is illustrated. It's a top view, with cover removed, of the accessory table of a costly, intricate dental unit. For reasons of assembly and wiring, the designer wanted the rotary switch in the position shown. And he wanted the control knob where it is, because that was the most desirable location for operation. Placing them in these positions created no problem—thanks to the flexible shaft. Consider the picture for a moment and you can appreciate that this use of flexible shafts to couple variable elements and their controls, removes practically all restrictions as to location and gives greater freedom in design.

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fluttering of the sheet, surface coatings like lacquer, or atmospheres heavy with steam, water, or palm oil.

The gage consists of two x-ray sources and one phototube pickup. Relative to the two x-ray sources, the pickup is actually at the apex of a right angle but is illustrated for simplicity in Fig. 1 as being aligned vertically with the two x-ray sources. Radiation from the lower source is directed up through the sheet being gaged so that the transmitted rays will strike the pickup. Rays from the upper source are directed horizontally through a

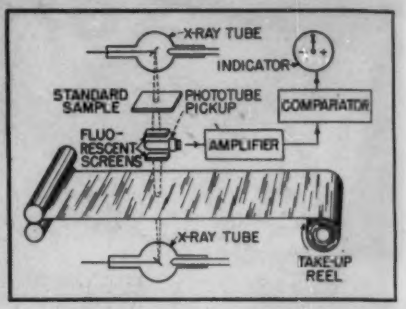

FIG. 1—Simplified schematic showing arrangement of units so that two x-ray beams strike the phototube pickup for comparison

standard sample of correct thickness to the same pickup. Radiations are emitted 180 degrees out of phase so that the rays alternate in striking the pickup and are compared in intensity after a large part of their radiation has been absorbed in the standard sample or test sheet.

Difference in the intensities of the rays is registered on the indicator instrument. At full deflection of the indicator needle a red light on the instrument goes on and a throw-out or other mechanism is actuated through electronic circuits.

Measures Glass Thickness

Equipment has recently been constructed for measuring the wall thickness of glass containers. In this system, the pickup is inserted within the container as shown in Fig. 2. It consists of a brass tube with one end opening to a housing containing the phototube and the other end cut on a 60-degree angle axially with respect to the tube. This diagonal cut has a fluorescent screen mounted in its plane. Thus the phototube looks down through the tube at the fluorescent screen.

A mechanical system brings the

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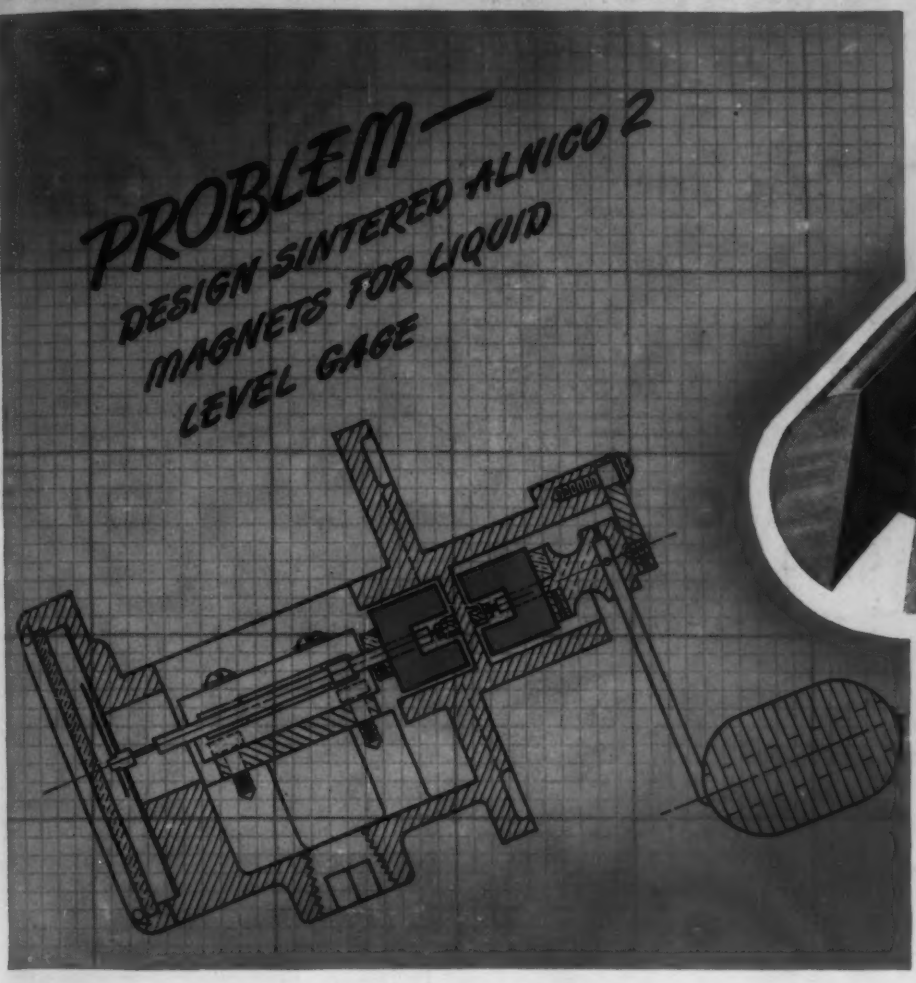
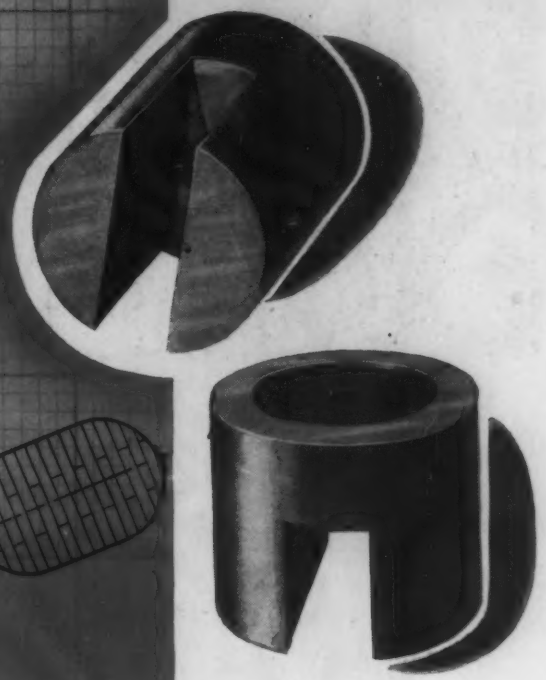
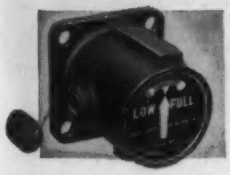


Here's another outstanding application for one of the many G-E permanent magnet materials—the magnetic liquid level gage manufactured by The Boston Auto Gage Company.



The Magnets that Guard your Transformer



Two G-E sintered ALNICO permanent magnets, separated by an aluminum diaphragm, function as a leakproof magnetic coupling in this gage to accurately indicate the level of the insulating liquid in transformers. The rise or fall of the float actuates the dial pointer by means of the coupling.

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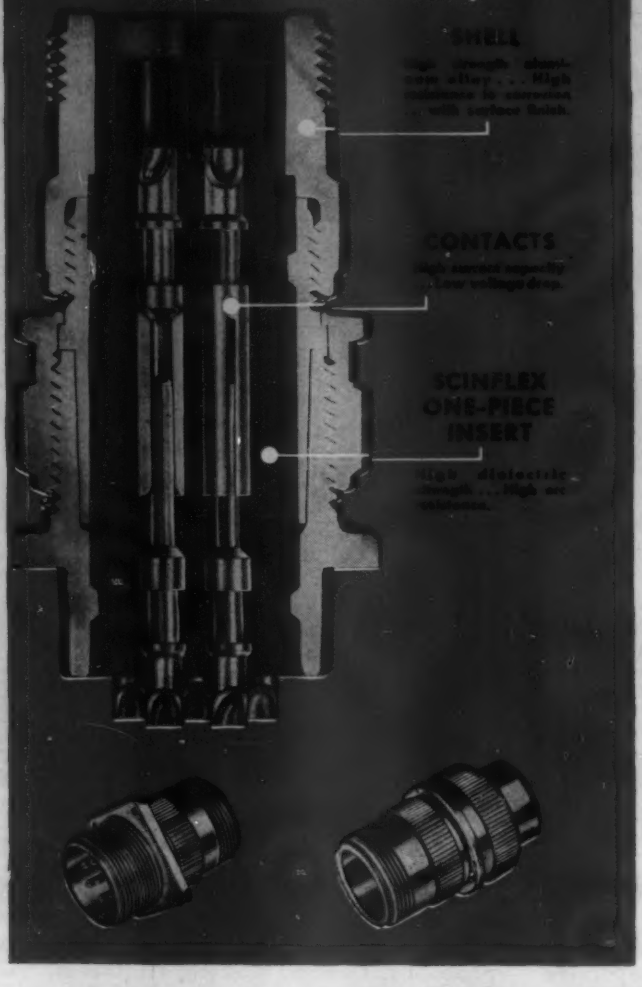

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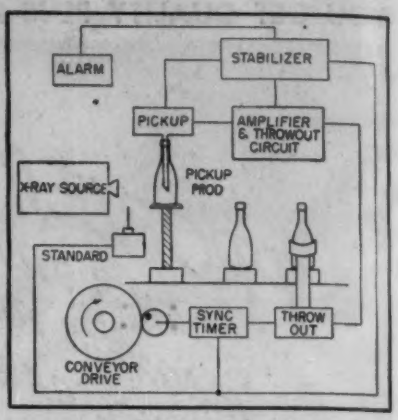

FIG. 2—A method of using the x-ray gage for measuring the thickness of a glass bottle

glass container up around the pick-up tube, rotating the bottle at the same time. Thus a point on the container describes a helix and the bottle wall is effectively scanned. If the wall thickness at any point is less than a predetermined minimum value, the gaging circuits operate to discard the defective container.

The phototube pickup consists of a photomultiplier surrounded by a fluorescent screen and enclosed in a light-proof cover. Absorption of x-radiation in the fluorescent screen excites the compound of the screen to visible luminescence which is picked up by the phototube and converted into current pulses. The latter vary in amplitude according to the thickness of the material.

Gage Circuits

The gage circuit (see Fig. 3) consists essentially of a 6SJ7 amplifier, a 6H6 clipper and base line restorer, a 6AC7 saw-tooth converter, and a pair of 6AG7's used in a comparator circuit. A 6AC7 photomultiplier stabilizer, a 6AC7 amplifier for a cathode-ray indicator, and a 6H6 duplex diode rectifier for a bias supply are also located in the gage chassis.

The output signal obtained from the anode of the 931A photomultiplier is applied to the control grid of the 6SJ7 through conventional capacitive coupling. The photomultiplier anode is maintained approximately 255 volts d-c above ground through 1.5 megohms resistance from the power supply of the gage circuit. The amplified signal from the 6SJ7 is then applied to the 6H6 clipper. The anode of this clipper is maintained at a

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negative potential with respect to the cathode. Thus, a positive pulse for the 6SJ7 will not be conducted across the 6H6 unless the pulse amplitude overcomes the bias between the elements on the clipper. Thus, by varying this d-c bias, the amplitude of the pulse as it may be applied to the next stage can be controlled.

The action of this tube also protects the indicating instrument in the event of thickness differentials

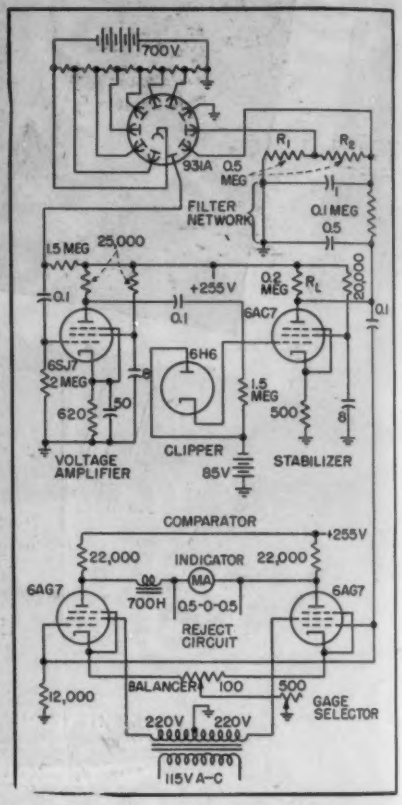

FIG. 3—Values of components and stages of the gaging circuit. The 6AC7 stabilizes the 931A photomultiplier

greater than 150 percent or complete removal of the test sheet. In either event one pulse becomes too small to pass the diode, and thus the pulse differential on the comparator is no longer proportional to the actual thickness difference. The indicating instrument will consequently never be subjected to much more than 150 percent of rated current.

The cathode of the 6H6 clipper is coupled to the control grid of the following 6AC7, which is a sawtooth converter. This stage in effect adds area to the pulses. This effect is accomplished by shunting the tube with a 1-μf capacitor.

The control grids of the two

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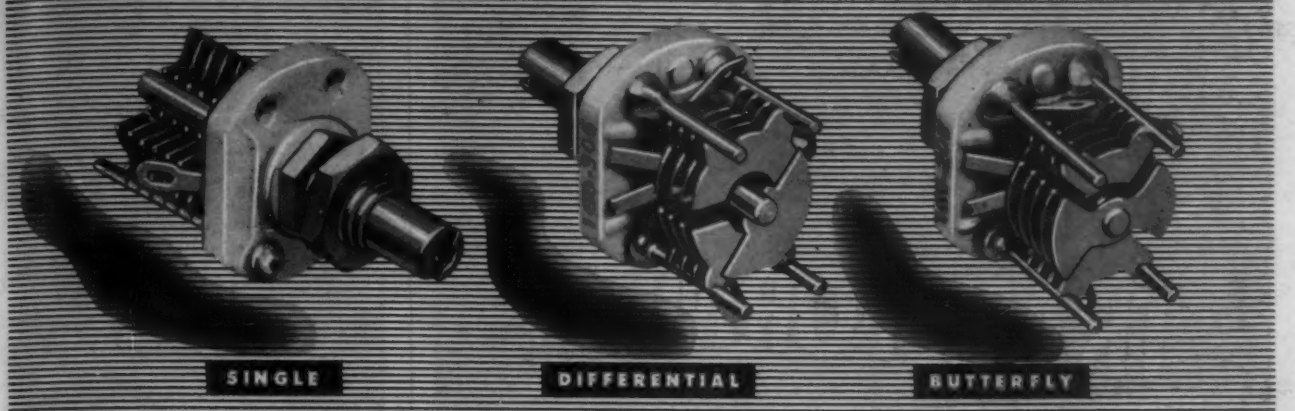

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For switching capacity from rotor to either of two stators, and for shifting tap on capacity divider. Available in four models: 1.84 to 5.58 mmf, 1.98 to 9.30 mmf, 2.32 to 14.82 mmf and 2.67 to 19.30 mmf.

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Applicable wherever a small split stator tuning condenser is required. Available in four models: 1.72 to 3.30 mmf, 2.10 to 5.27 mmf, 2.72 to 8.50 mmf, and 3.20 to 11.02 mmf.

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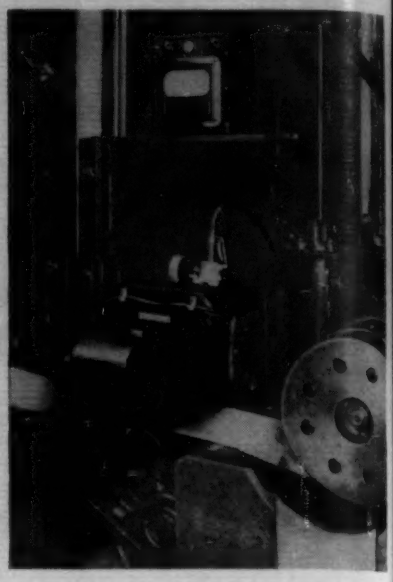

Setup of the x-ray thickness gage for checking copper strip in a cold reduction mill

tubes in the comparator circuit of Fig. 3 are in parallel. The cathodes are grounded through a potentiometer balancer and a gage-selector rheostat located on the control panel. The screen grids are connected to the transformer so that the applied potentials are 180 degrees out of phase. Each tube thus conducts only when its screen grid is positive. The magnitude of the plate current during conduction depends on the magnitude of the pulse applied to the grid by the x-ray tube channel that is operating during that same half cycle. For equal pulse amplitudes on both half cycles, as occurs when sample and unknown are equal in thickness, the voltage drops across the two 22,000-ohm plate load resistors will be equal and there will be no voltage acting on the meter. For differences in thickness, the zero-center meter will indicate the deviation in thickness by deflecting in the proper direction. The high-reactance choke prevents a-c voltage from acting on the meter.

Photomultiplier Stabilizer

Phototube output is held constant despite inherent drift of secondary-emission tubes by automatically controlling the dynode potentials and in effect controlling the amplification of the phototube. The output pulse due to visible light emitted by the fluorescent screen is amplified by the phototube and by the 6SJ7. The amplified pulse is

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The chart above indicates main routes of airlines using Collins radio communication equipment in the air, on the ground, or both. This tremendous acceptance had its beginning in the middle thirties, and is the result of early and never-ending Collins research and development in the field of aviation communications.

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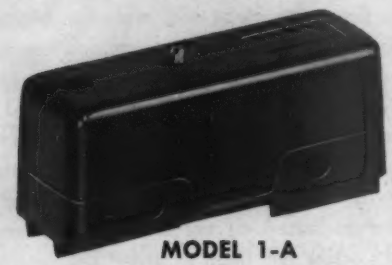

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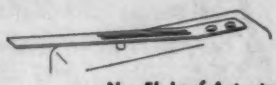

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applied to the grid of the 6AC7 stabilizer which is biased far beyond cutoff and will not conduct unless the signal pulse amplitude nearly equals the d-c bias. If the stabilizer tube plate current increases due to an increase in pulse amplitude, the average drop across R_2 increases and the drop across R_1 and R_3 decreases. This lowers the voltage on photomultiplier dynodes 8 and 9 sufficiently to counteract the increase in signal pulse amplitude due to drift.

Operating Conditions

At times, signal amplitude increases to quite high values due to thin test material or complete removal of the test material. The diode serves to clip off the lower portion of the signal, reducing the average a-c value and preventing excessive positive grid swings that might damage the stabilizer tube.

Signal input to the phototube is set originally so that an optimum signal current flows through the stabilizer tube. This sets the voltage across R_1 and R_3 at its midvalue, as required for drift compensation in either direction.

The operator may select the gage of stock to be run by making a simple adjustment of a calibrated rheostat connected in the cathode circuit of the comparator and located at the remote control panel.

Optimum conditions include use of a fluorescent screen causing highest photomultiplier response, restriction of the x-ray beam to that small area on the fluorescent screen most effective in causing photomultiplier response, use of x-ray wavelengths for which absorption in the fluorescent screen is nearly complete, and use of a refined 931A phototube for maximum light sensitivity.

X-Ray Tube Stabilizer

Operation of the x-ray sources without stabilization results in undependable gage indication. X-ray tube current is dependent upon filament temperature. If tube currents in the two heads are originally set at equal values, it is unlikely that they will still be equal an hour later. To maintain automatically identical current magnitudes at all times, the tandem milliampere stabilizer circuit shown in Fig. 4 is

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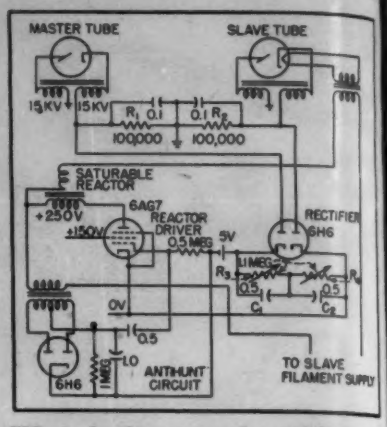

FIG. 4—In the x-ray tube stabilizer, the anode current of the master tube controls the filament current of the slave tube

provided. This circuit uses current of one tube (the master) as reference and makes the current of the slave tube follow it.

The cathode currents of the x-ray tubes cause voltage drops across resistors R_1 and R_2 and these are applied to a 6H6, charging C_1 and C_2 to voltages proportional to the respective x-ray tube anode currents.

Rheostats R_3 and R_4 adjust the time constants of the two R-C circuits, enabling the operator to vary the magnitude of the slave current. The bias on the control grid of the 6AG7 pentode is the algebraic sum of the two capacitor voltages and the bias battery voltage. Plate current of the pentode flows through the d-c winding of a saturable reactor. The greater the plate current, the smaller the a-c voltage drop across the reactor and the higher is the filament current in the slave tube, and vice versa. An antihunt arrangement using a feedback transformer and a duplex-diode rectifier, capacitance-coupled to the grid circuit, prevents oscillation that might otherwise result from high sensitivity and quick response.

Other Applications

Applications for an x-ray thickness gage include measurement of the thickness of linoleum, laminated plastics, sheet glass, many types of sheet metal, and paper and cardboard. One interesting application that wouldn't work was counting of bundles of banknotes to determine exactly how many bills above and below the standard number (100, 500, or 1,000) were in a given bundle. It sounded simple, until a trial showed the thicknesses of in-

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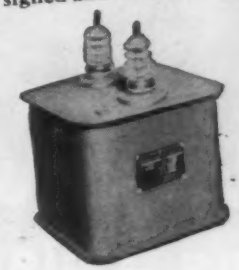
Resonant-charging reactors, accurately designed and constructed for radar service. Usually required in ratings of 40 kv and below, 1 ampere and below and 300 henries and below. Higher ratings are being built, and can be considered. When required, small- and medium-size designs can be provided with 3 to 1 range of inductance adjustment.



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dividual bills varied as much as 10 percent.

The photograph illustrated on page 162 shows the instrument as it is installed in a cold reduction mill. The Westinghouse x-ray thickness gage checks copper strip as it passes to the take-up mandrel at right. Mounting the x-ray generators as shown (below the moving strip and above and to the rear) permits the necessary right-angle relation with respect to the phototube pickup in the cylinder above the strip.

Ultraviolet Flame Detector

IN DEVELOPING counter tubes to measure the intensity of soft x-rays, physicists at the Naval Research Laboratory observed that these tubes were sufficiently sensitive to ultraviolet radiation to make practical the construction of a counter, highly sensitive to ultraviolet radiation from an open flame, and thus having advantages for fire alarm equipment.

The basic Geiger-Muller counter tube, of which this unit is a variation, consists of a cylindrical cathode and a centered anode wire all enclosed in a glass envelope as shown in Fig. 1. The tube is filled

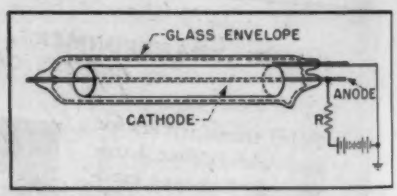

FIG. 1—Construction of basic Geiger-Muller counter tube. To sensitize tube to ultraviolet, surface of copper cathode is slightly oxidized and tube is filled with mixture of argon and alcohol vapor at low pressure. Quartz window in the glass envelope admits ultraviolet radiation

with a single gas or a combination of gases at low pressure, and a potential of the order of 1,000 volts is applied across the two electrodes. This voltage is carefully adjusted so that the tube is operating just below the point where self-sustained discharge can occur. Under these conditions, when a single electron is introduced into the tube, a momentary discharge is triggered. Proper design of the counter and its associated circuit permits the discharge to be rapidly quenched. The elec-

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As with all other VARIACS, output voltages are continuously adjustable from zero to 17% above line voltage.

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	TYPE V-20	TYPE V-20H
LOAD RATING (KVA)	3.45	2.3
Input Voltage	115	230 or 115
Output Voltage	Zero to 115 or 135	270 or 230
Rated Current (Amperes)	20	8
Maximum Current (Amperes)	30	10
PRICE	$55.00	$55.00

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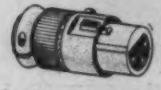

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trons causing the discharges can originate as the result of various forms of radiation. In a light-actuated counter, they originate as a result of photoelectric emission from the cathode.

To permit the use of the counter in a lighted place, it is necessary that it be particularly sensitive to those components of the spectrum that are produced by radiation from a flame, and that it be relatively insensitive to the spectral components of sunlight. For this purpose, the counter must have a threshold of sensitivity less than 2,900 angstroms. A counter tube having a copper cathode surface will meet this requirement provided that this surface is oxidized slightly. The introduction of a small amount of alcohol vapor in the counter tube also helps to reduce the wavelength at which the sensitivity threshold occurs.

Construction of Counter

Based on the principles outlined, an ultraviolet counter tube was constructed with a copper cathode having a slightly oxidized surface, and a 5-mil tungsten wire anode. The anode was centered by means of two punched mica discs. A quartz window cemented in the glass wall with Glyptal admits ultraviolet radiation. The tube was filled with a mixture of alcohol vapor at 4 mm and argon at 4 cm (mercury-pressure).

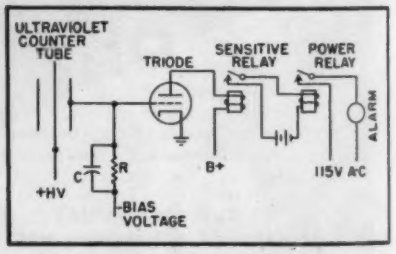
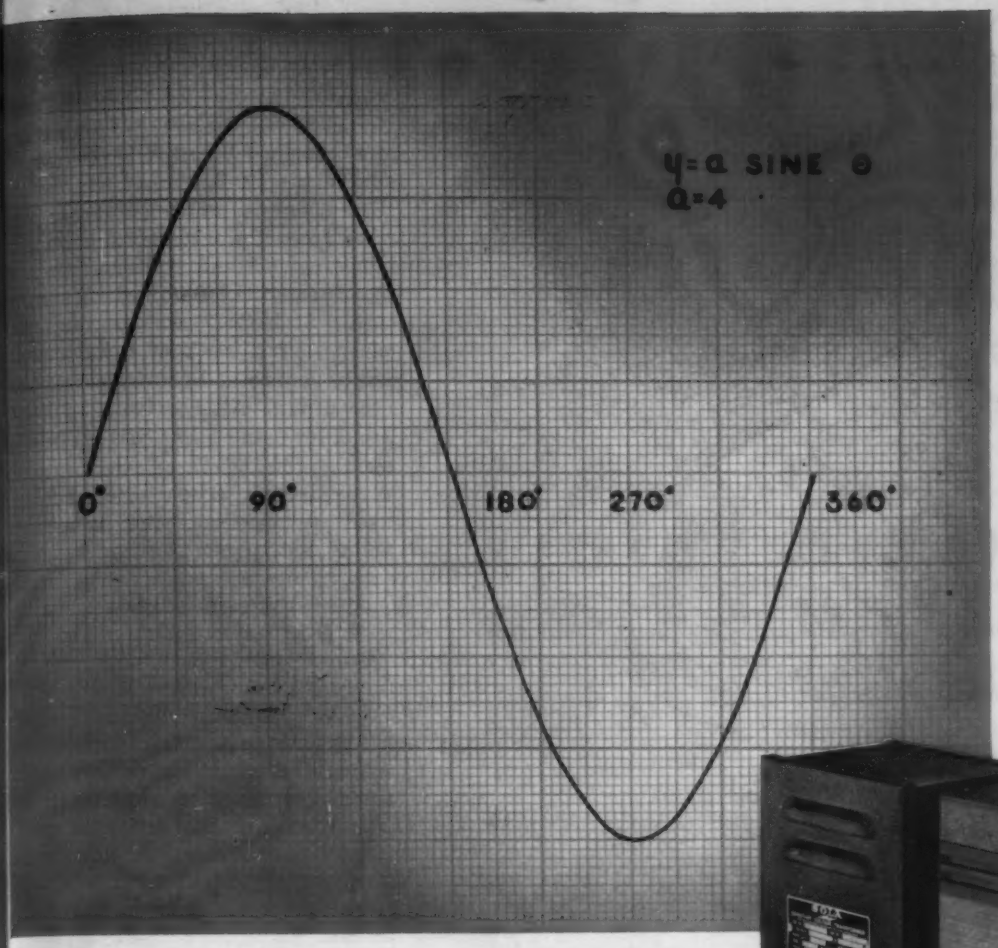
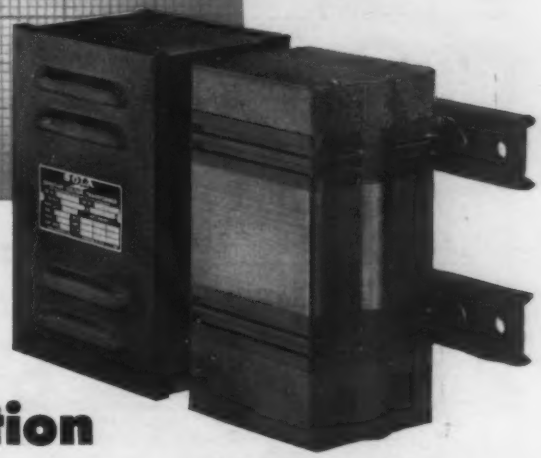


FIG. 2—Simple ultraviolet counter fire-alarm circuit

The counter tube was connected as shown in Fig. 2 to the input of an amplifier. The R-C input circuit was chosen to have a time constant of about five seconds. Thus, infrequent aperiodic discharges of the counter, occurring for small intensities of radiation, are smoothed out to produce steady currents. With the time constant so chosen,





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All the advantages of a separate lock-washer and screw assembly are now combined in a single cost-cutting unit. As the lock washer is an integral part of the head this time-saving screw is driven with the same speed as a regular screw. It automatically eliminates lost time and waste, as well as the hazards of driving screws without washers in applications where washers are required.

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the relay operated when the input current exceeded 10 photoelectrons per second. An alternative circuit arrangement using a thyratron is shown in Fig. 3.

If it is desired to operate the device from the 110-volt a-c line, a transformer and voltage doubler can furnish the required high voltage. Stabilized voltage can be picked off a bank of ½-watt neon lamps connected in series across the d-c output. Alternatively, with an amplifier using a low-current triode such as the 1G4-G, a pack of miniature aircraft B batteries can be used to produce the necessary voltage.

Performance

In a one-minute run, the counter described can detect a photocurrent of only five electrons per minute against the normal background count inherent in the device. This small electron flow corresponds to a current of the order of 10^{-3} ampere. The most sensitive type of photocell can measure photocurrents of the order of 10^{-16} ampere.

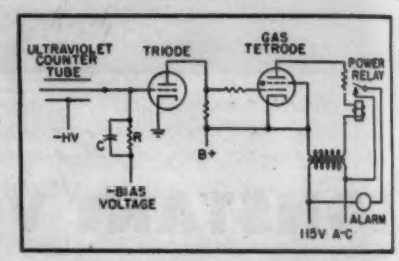
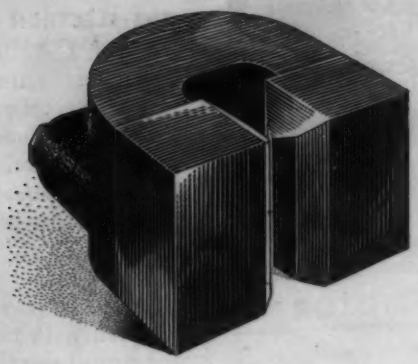


FIG. 3—Sensitive relay required in circuit of Fig. 2 is eliminated by use of thyratron

In testing thermal alarms, the Bureau of Standards has used a standard flame obtained by igniting five square feet of alcohol in a flat pan. In one series of tests, this source was ignited in a room measuring roughly 13 feet high and having about 2,000 square feet of floor space. With detector elements on the ceiling and the fire pan on the floor in the center of the room, it generally required more than a minute to actuate the alarm. With a similar source, the ultraviolet counter triggers the alarm in a few seconds when mounted 200 feet from the fire pan. Its response is independent of room shape or ventilation and is limited only by the cone of vision.



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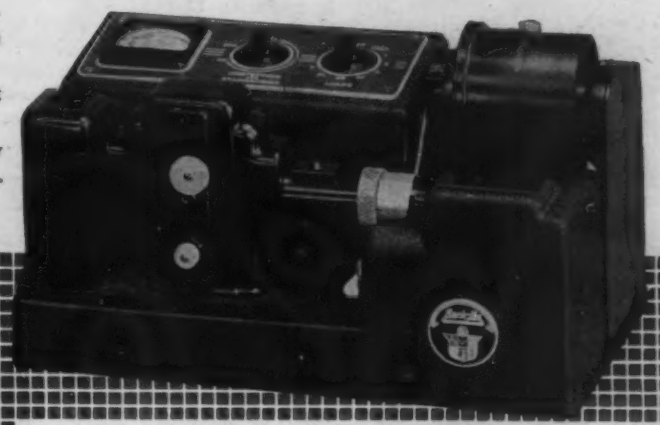

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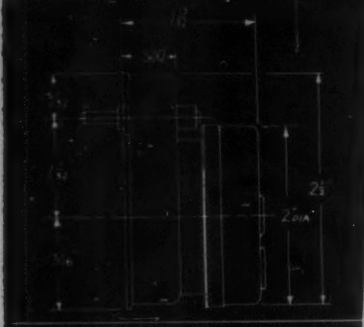

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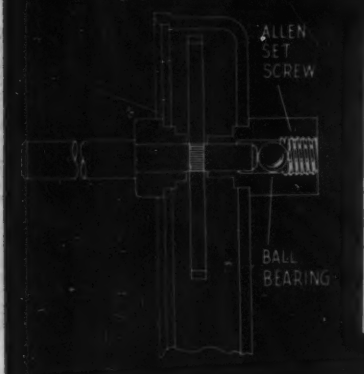

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(continued from p 140)

dividual slits are arranged on tracks along the focal curve. The receivers can be positioned as necessary on tracks to monitor lines from elements of interest. Each receiver of the Quantometer built by the Applied Research Lab. consists of a photomultiplier tube (supplied from a single high-voltage rectifier in common with the other receivers) and an integrating amplifier (with individual power supply). A separate, multiple-channel recording console punches tapes from which, after calibration, the chemical percentage of each element can be read. Once set up, the meter determination has an average deviation of only 0.012 percent.

Development and Applications of the Skiatron

By G. Wikkenhauser
Technical Director, Schophony Ltd. Wells, Somerset, England

Dislocation of electrons in or from their atoms in crystal lattices usually results in coloration. This effect, recently utilized in x-ray treatment and inspection of gems, is used to produce the visible image

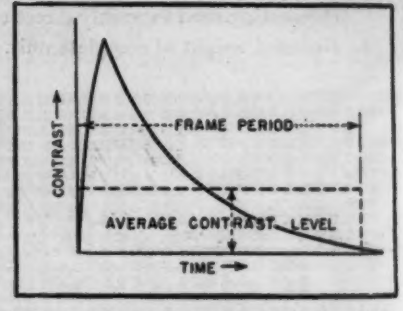

FIG. 1—Density-time characteristic of electron opacity phenomena

in the Skiatron type cathode-ray tube. Although experimentally developed for use in television, this tube offers several advantages for radar indicators, especially its long persistence with concomitant discrimination against noise by signal integration.

Development and Characteristics

Intense coloring of various alkali halide crystals that results from cathode-ray bombardment, discovered in 1894 by E. Goldstein, and further studied by Pohl, Mott, and Gurney, is used to produce opacity in the tube screen. When a thin layer of these crystals is so bom-

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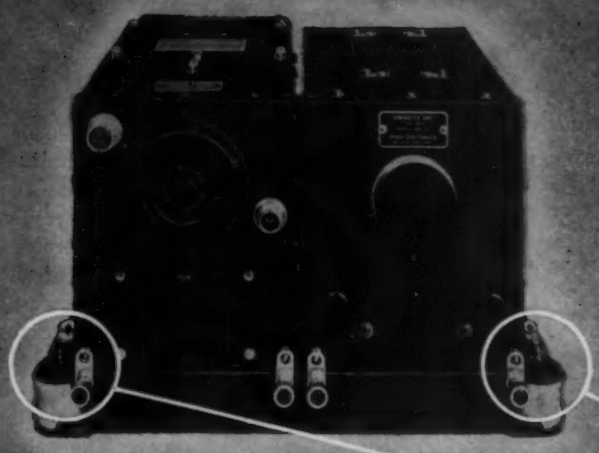

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FIG. 2—Large-screen plan position indicator used by British Admiralty

barded, some electrons are displaced from the halides and occupy positions in the faults of the crystal lattice where they vibrate at characteristic frequencies. Because the frequency of vibration lies in the visible spectrum, and because these displaced electrons can absorb light at their characteristic frequencies, a dark pattern is produced on the originally semitransparent crystal layer. The color of the pattern is the complementary color of the absorption.

The most commonly used material is potassium chloride whose absorption is in the green region of the spectrum, thus the dark pattern appears magenta. In potassium bromide the absorption is in the bluish range, so that the pattern is brownish; sodium chloride gives an orange trace. As the electrons absorb further energy either from light or heat rays they return to their stable positions and the dark trace disappears.

This phenomenon was applied to television tubes by A. H. Rosenthal in 1938, but, although he obtained television images on Skiatrons of the BBC 405-line interlaced transmission, it was realized that much work was required to perfect the technique. The images lacked sufficient contrast because of the relatively long persistence of the trace. Time required for a trace to disappear is a function of the degree of discoloration, dark traces dissolving most slowly. To obtain fast enough decay for reproducing 25 pictures per second, the darkening had to be limited to very faint traces. Figure 1 shows a typical buildup-decay characteristic. De-

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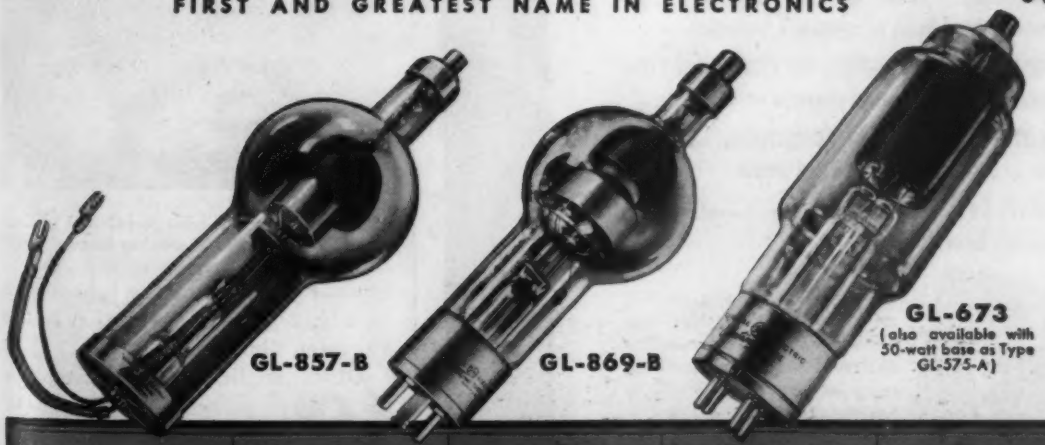

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GL-673
(also available with 50-watt base as Type GL-575-A)

Type	Cathode voltage	Cathode current	Anode peak voltage	Anode peak current	Anode avg current
GL-866-A	2.5 v	5 amp	10,000 v	1 amp	0.25 amp
GL-8008	5 v	7.5 amp	10,000 v	5 amp	1.25 amp
GL-673	5 v	10 amp	15,000 v	6 amp	1.5 amp
GL-869-B	5 v	18 amp	20,000 v (*15,000 v)	10 amp	2.5 amp (*5 amp)
GL-857-B (*Quadrature operation)	5 v	30 amp	22,000 v	20 amp (*40 amp)	5 amp (*10 amp)

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spite these limitations, the fact that the tube could be used as a light valve, controlling an auxiliary light source, recommended it for use in projection systems for producing large television images.

Application to Radar Indicators

In applications other than television, where the trace could remain for some time, the characteristic of the Skiatron screen is desirable. One such application is to ppi instruments, especially the projection type of Fig. 2, on which shore lines and other fixed objects build up to high contrast and paths of aircraft and ships are shown. To cancel the trace the screen is irradiated with heat and light.

Parallel developments were made by several German firms including Lorenz and Telefunken. To cancel the trace on these tubes, heat was applied directly. The halide screen was formed on a thin sheet of mica on which was also a tungsten film thin enough to be transparent to visible light but yet electrically conductive. When the trace was to be erased, current was passed through the tungsten film producing a sufficiently high temperature to dissolve even a very dark trace in from 5 to 10 seconds. The metal

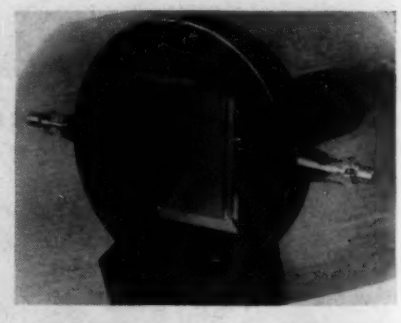

FIG. 3—Dark-trace tube developed in Germany contains erasing heater

caps at the sides of the tube shown in Fig. 3 provide connection to the tungsten film.

Other applications utilizing the long persistence characteristic of the Skiatron have been made. To track every plane within a 50-mile radius of the All-Weather Flying Center, Wilmington, Ohio, such a tube is being used. The transient recording oscillograph made by Scophony produces a persistent trace that can be studied or photographed without need for precise synchroni-

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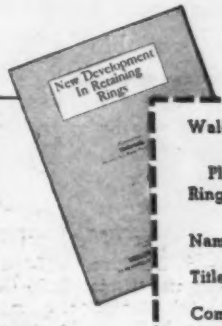

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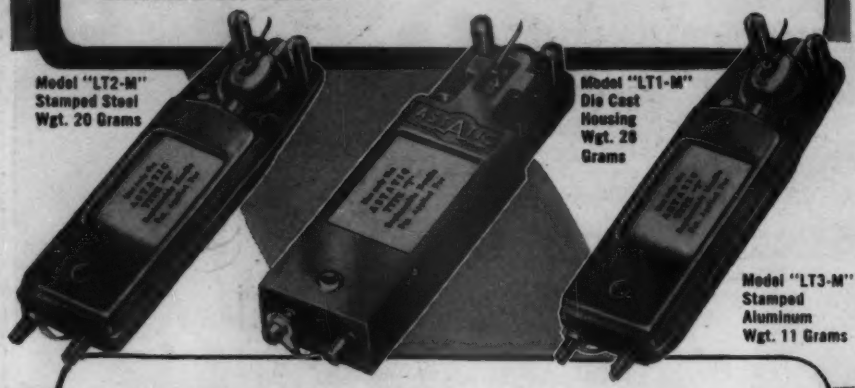

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FIG. 4—Dark trace persistence is such that trace remains after tube is unplugged

zation with the occurrence to be recorded. Figure 4 is a rather unique photograph of a British tube on which a damped 25-cps wave was recorded; the tube was then removed from the associated equipment and the photograph made, the trace still remaining on the screen. The British Services Electronic Research Laboratories have demonstrated a facsimile transmission and reception system in which a 500-line picture, scanned over a period of one second, is reproduced by this electron opacity technique.

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Measuring R-F Power with a Thermopile

By GUY P. WALKER

Naval Research Laboratory
Navy Department
Washington, D. C.

DETERMINATION of radio-frequency power produced by an oscillating vacuum tube or lost within it or its associated circuit is difficult. Closely coupling measuring equipment to the circuit may change the operating conditions. Although the optical pyrometer method does not disturb the tube or circuit, it is subject to error from the nonuniform distribution of temperature over the anode during calibration (calibration usually being done with d-c in

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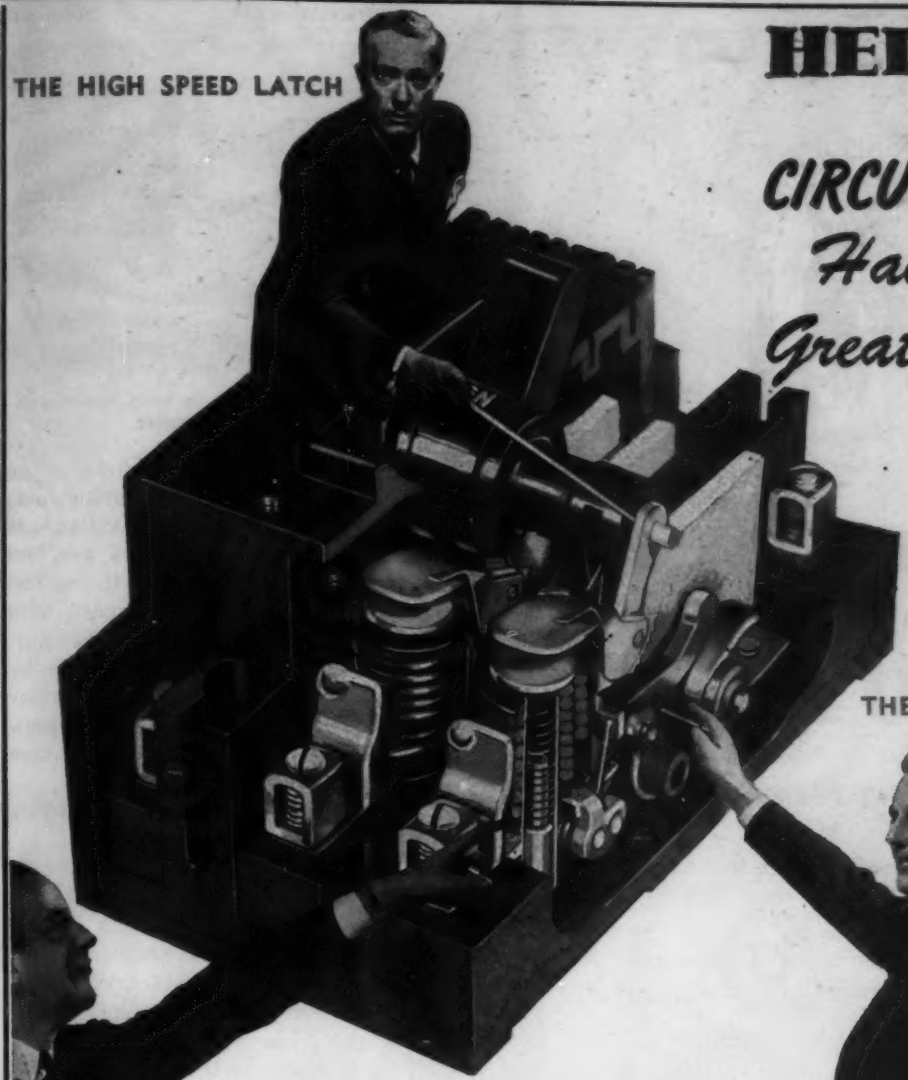

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Above sketch shows the action of the Time Delay Tube, which prevents the breaker from opening on sudden inrush current, but allows it to open on sustained overloads. This is done by means of the plunger action in the liquid-filled tube. The speed with which the plunger is drawn toward the magnetized pole piece depends on the viscosity of the liquid. (At left —plunger in normal position. At right — after overload has attracted plunger to pole piece, opening contacts).

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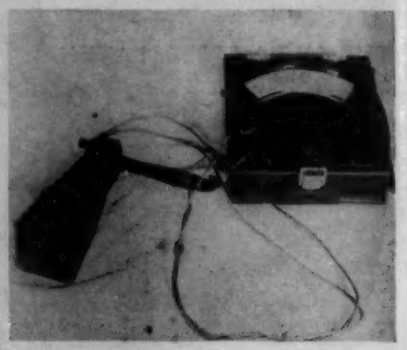

FIG. 1—Thermopile in horn operates indicating meter

which case the grid shadows on the anode are well defined; during operation, when the grid voltage is swinging, these shadows are less defined). Furthermore, the optical pyrometer can only be used with tubes whose anodes show color during operation. The thermopile, by measuring radiated heat rather than light, is free from these limitations, and retains the advantage of not disturbing the circuit.

Method of Use

In a self-excited oscillator, d-c input power to the tube is consumed in (1) tube losses, (2) circuit losses, and (3) useful power output. Circuit losses and useful power output taken together make up the total r-f power output. Because d-c input power to the tube is readily obtained, if tube loss can be measured, subtracting this loss from d-c input power gives total r-f power output. A lumped value of the various circuit losses can be obtained if both tube loss and useful power output are measured and the useful power output subtracted from total r-f power output.

A sensitive but rugged and inexpensive thermopile located at the focus of a horn whose interior is highly polished has been found to be sufficiently directional to respond to the heat radiated from a given tube toward which it is aimed and to exclude small quantities of heat radiated from sources outside the area seen by the orifice of the horn. However, the horn covers a large enough area of the anode not to make the equipment sensitive to localized temperatures. Figure 1 is a photograph of this equipment and its associated meter. The horn and shielded meter leads prevent interference from r-f fields produced by

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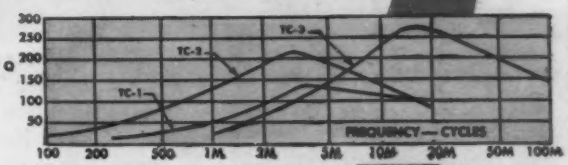

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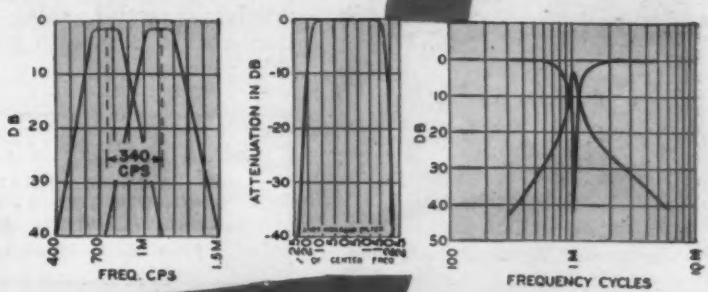

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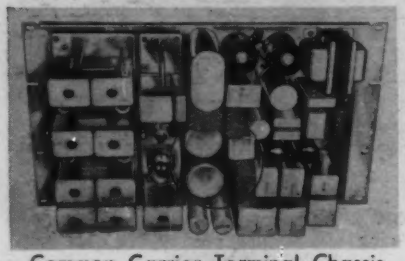

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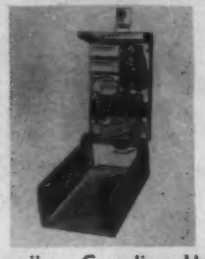

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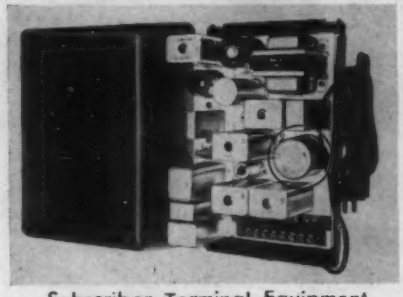

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the circuit under test. The meter used with the thermopile is a sensitive d-c microammeter whose resistance should be such as to produce a reading of at least half scale under the prevailing conditions of radiation being received by the thermopile.

A calibration curve is made of d-c input power vs thermopile reading with the tube operating statically. As would be expected, current from

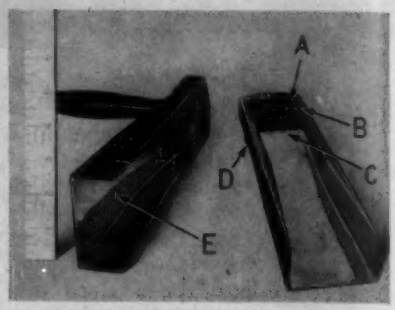

FIG. 2—Open horn shows internal shape and location of thermal junctions. There are 19 cold junctions (A) and 19 hot ones (C), the later being blackened and located along the focus of the horn. The Thermopile is insulated (B) from the polished aluminum horn (E) and leads brought out to terminal posts (D). The equipment is available through Central Scientific Co., Chicago

the thermopile varies linearly with respect to the power dissipated within the tube. During calibration the tube dissipation is considered to be the sum of the plate and screen input powers. Filament power is neglected because it is considered to be constant throughout calibration and operation, its only effect being to produce a finite intercept of the calibration curve. Control grid power for most tubes is negligible during calibration and in self-excited oscillators is furnished by the anode supply. After calibration, the tube circuit is adjusted for the oscillating condition without disturbing the distance between tube and thermopile or their positional relationship. However, the same thermopile and meter can be used to measure a wide range of power by varying the distance between thermopile and radiating tube, making suitable calibrations at these distances.

With the tube oscillating, a thermopile reading is obtained and, by reference to the calibration curve the power dissipated within the tube is determined. As indicated above, subtraction of this value

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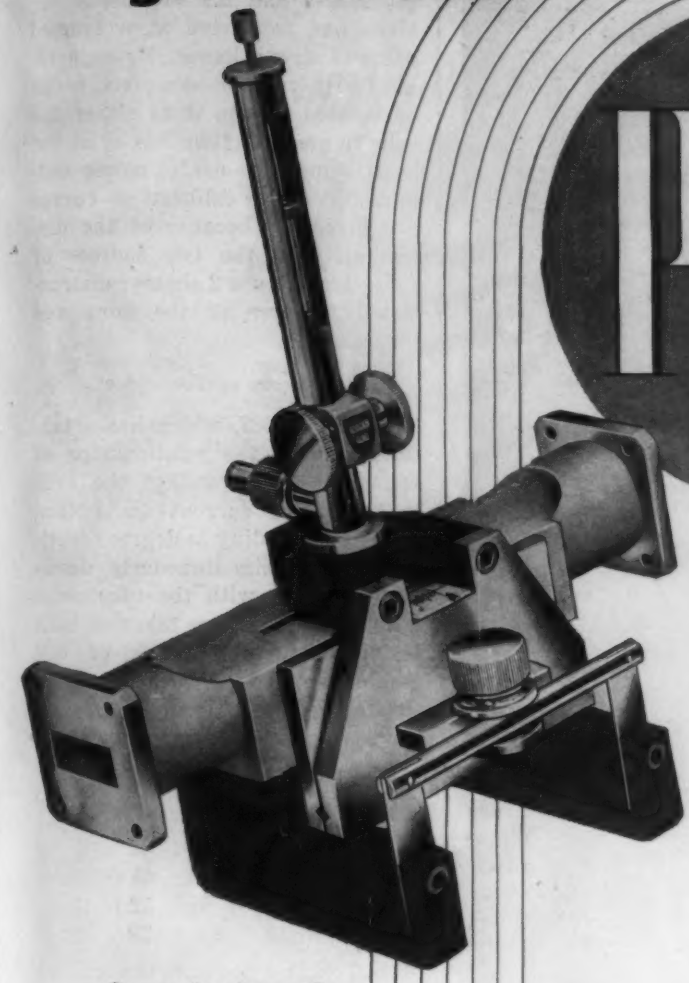

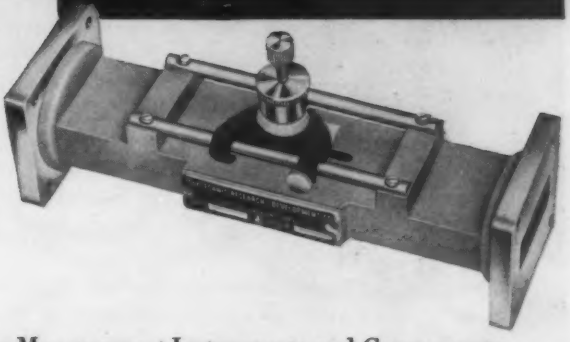

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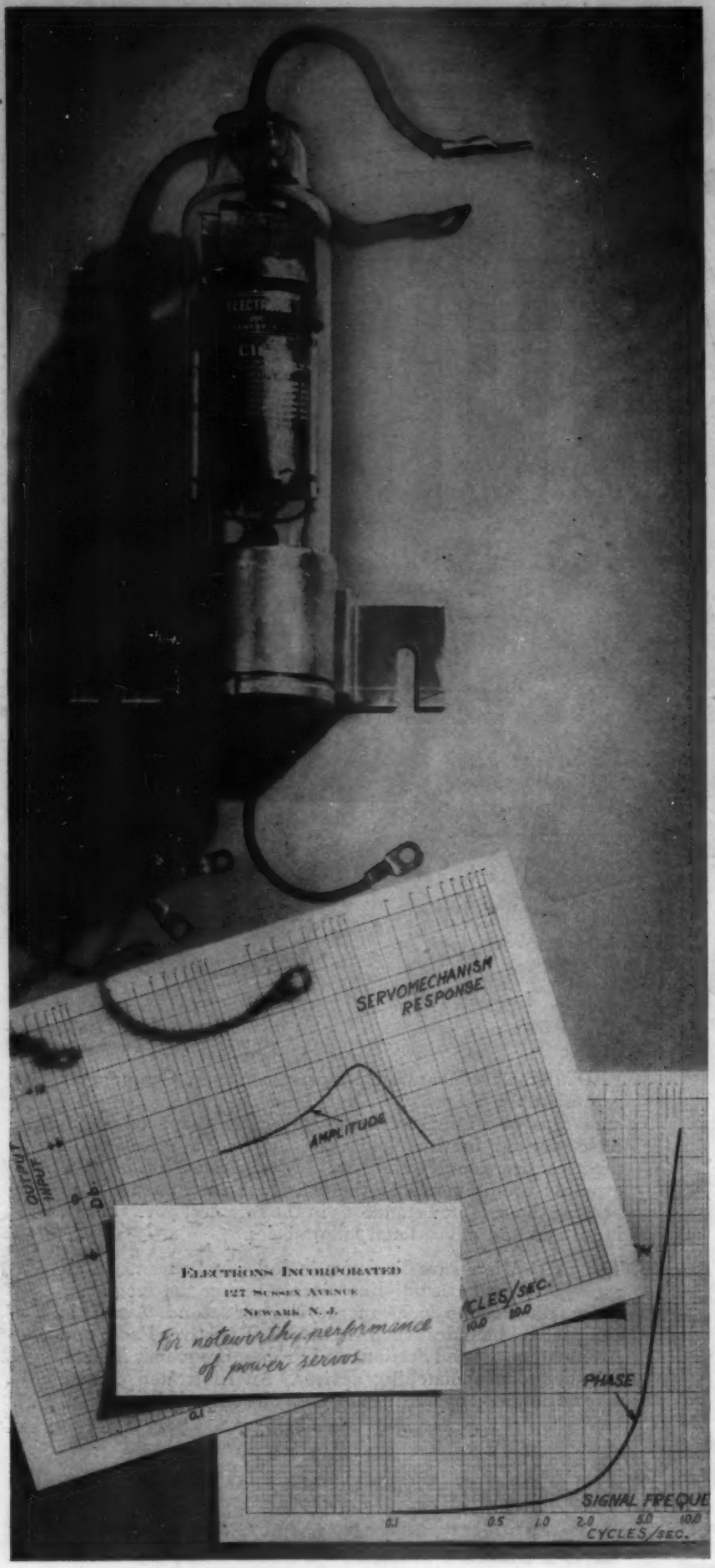

from the d-c input power gives the total r-f output or, in other words, gives the sum of circuit losses and useful power output. Measurement of the useful power output by a lamp and photocell or by a lamp or other load and the thermopile enables one to arrive at a lumped value of circuit losses. By supporting the thermopile on a pivot, it can be rotated to aim it at either the tube to measure tube loss or at the load to measure useful power output. Separate calibration curves are necessary because of the dissimilarity in the two sources of radiation. Figure 2 shows constructional features of the horn and thermopile.

Accuracy of Technique

Using a 4E27, which has a tantalum anode, the relationships of watts dissipated within the tube to thermopile current and optical pyrometer reading in degrees centigrade were simultaneously determined. Then, with the tube oscillating, readings were taken on both instruments as a check of one method against the other to give the following tabulation

Optical Pyrometer	*Thermopile*
Tube loss in watts	
37	44
49	51
57	52
80	79
Total r-f power in watts	
117	110
138	136
168	173
220	221
Circuit losses in watts	
21	14
20	18
30	35
29	30

In general, the readings agree with each other within a few percent. However, scattered readings are in considerable disagreement. The fact that the disagreements are not consistently in the same direction indicates that the personal element may be an important factor. Because matching colors of a small area of the tube anode and of a heated filament within the optical pyrometer is more difficult than

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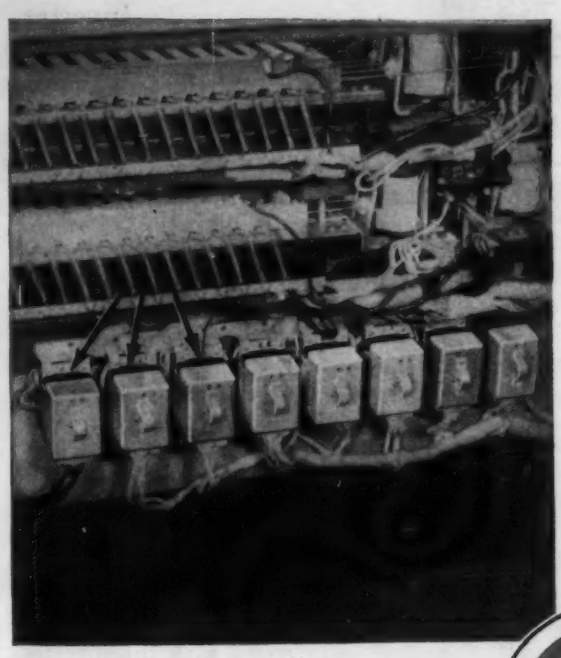

Above photograph, by courtesy of The Rudolph Wurlitzer Company, indicates the position of referred-to plastic plugs in the Wurlitzer Organ. Arrangement facilitates inspection and ready access for disassembly of the interior Wurlitzer Organ parts.

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reading a 5-in. meter scale, the disagreements in readings are most likely due to inaccuracies in reading the optical pyrometer than to errors in the thermopile. Therefore the thermopile is at least as accurate as other commonly used equipment for measuring r-f power.

Because tubes warm up slowly, approaching their stable temperatures asymptotically, readings cannot be taken quickly. A 50-watt tube requires about 8 minutes to reach a point where reasonably accurate readings can be taken. When making readings with the thermopile, ambient temperature should not change widely. Changes in direction or velocity of air currents near the tube or thermopile can introduce errors. However, as the data presented indicates, the thermopile with its directive horn is a very useful instrument, especially in the laboratory where tubes can be held at equilibrium long enough for the reading to have meaning.

Directly Coupled Phase Inverter

By E. Johnson
Brooklyn, N. Y.

Direct-current symmetry and stability of output are obtained from the phase inverter shown in the accompanying diagram. Because of these properties, the circuit is useful in handling flat-topped pulses, low frequencies and the like. The indicated values of the components, although considered optimum for the specific application for which this circuit was developed, should be taken as suggestions rather than absolutes.

Operating Conditions

The upper half of the inverter is recognizable as a cathode-coupled amplifier[1,2]. The output of this half is in phase with the inverter input.

The lower half is the same as the upper half but with its grids interchanged. With respect to quiescent conditions, the lower half of the circuit behaves identically to the upper half. However, the output of the lower half is 180 degrees out of phase with the inverter input. The inherent gain

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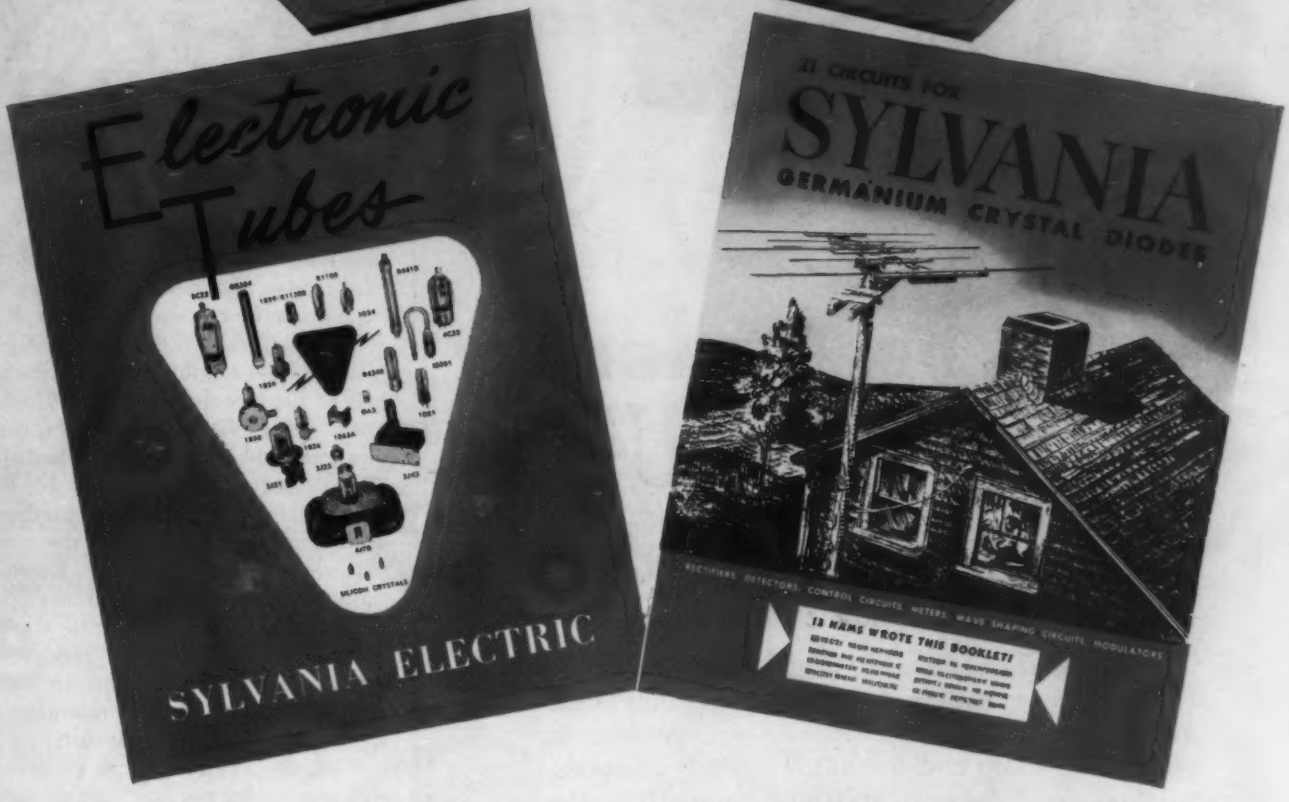

Sylvania's revised catalog, "Electronic Tubes," lists ratings, characteristics and typical applications of more than 75 special tubes and devices, including: Semi-conductors, Microwave Tubes, Industrial Electronic Tubes, Radioactivity Detection Tubes, Special Purpose Tubes. Catalog gives cross-references to detailed literature available from Sylvania on each type.

New 8-page booklet shows a total of 21 receiver, transmitter and test and control circuits utilizing Sylvania Germanium Crystal Diodes and Duo-Diodes. Originated by amateur radio operators, these circuits will be of interest to communications and industrial electronics engineers.

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MAKERS OF ELECTRONIC DEVICES; RADIO TUBES, CATHODE RAY TUBES, FLUORESCENT LAMPS, FIXTURES, WIRING DEVICES; ELECTRIC LIGHT BULBS

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500 Fifth Avenue, New York 18, N. Y.

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Please send me the following literature:

- ☐ **Electronic Tubes**
- ☐ **21 Circuits—Germanium Crystal Diodes**

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THE TURNER MODEL 22X-22D

Crystal or Dynamic Microphone

Leading manufacturers of communications, sound, and recording equipment specify the Turner Model 22 as standard for microphone performance. Its accurate pickup and smooth, wide-range response is engineered for both voice and music. Up-to-the-minute styling adds distinction to any installation.

The Turner Model 22 is easy to handle, convenient to use. Full ninety degree tilting head permits semi- or non-directional operation. Furnished with removable 7 ft. quick-change shielded cable set.

MODEL 22X is engineered with a high quality, humidity protected crystal in mechanical shock-proof mounting. Equipped with windgag and barometric compensator. May be used indoors or out. Response: ± 5 db from 50—9000 c.p.s. Level: 52 db below 1 volt/dyne/sq.cm.

MODEL 22D features high quality magnets in a well balanced acoustic circuit with adequate shielding to reduce r.f. pickup. Built to withstand heat, cold, humidity. Response: ± 5 db from 50—9000 c.p.s. Level: 54 db below 1 volt/dyne/sq.cm. at high impedance.

For thoroughly dependable performance, plus modern streamline styling— Turn to Microphones by Turner. Write for Complete Microphone Catalog.

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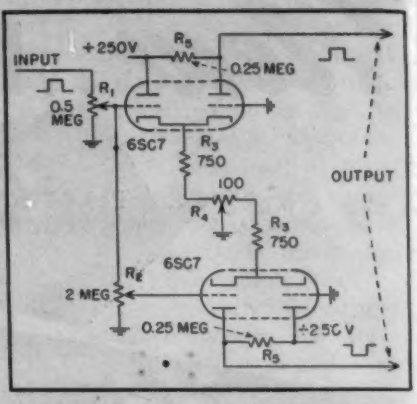


Phase inverter is directly coupled

of the lower half is about half that of the upper half so that an adjustment of the potentiometer R_2 is necessary to equalize the outputs of the two halves. Overall gain of the inverter is controlled by R_1.

Potentiometer R_4 is adjusted to make the d-c output voltage of each half of the circuit equal, the adjustment being made in the absence of signal and before R_2 is adjusted. The subsequent adjustment of R_2 does not necessitate any further adjustment of R_4, making the circuit very easy to balance. Essentially, each half of the circuit operates independently of the other half so that there is no tendency towards regenerative drifting and critical adjustment that characterize many comparable circuits.

With the typical values of components as shown, the circuit has a voltage gain of about 20 and handles inputs up to two volts without appreciable distortion. Use of 6SN7's would have reduced the gain to about seven. Graphical analysis offers a convenient means of investigating the performance of the circuit and provides a guide for selecting the components[3]

REFERENCES

(1) G. C. Szikiai and A. C. Schroeder, Cathode-Coupled Wide-Band Amplifiers, *Proc IRE*, p 701, Oct. 1945.
(2) K. A. Pullen, The Cathode-Coupled Amplifier, *Proc IRE*, p 402, June 1946.
(3) M. S. Rifkin, A Graphical Analysis of the Cathode-Coupled Amplifier, *Communications*, p 16, Dec. 1946

SURVEY OF NEW TECHNIQUES

NBS CASTING RESIN, whose properties were described (ELECTRONICS, p 136, July 1947), is being commercially produced by The Mathieson Alkali Works. Because of its low shrinkage upon polymerization and its electrical and dimensional

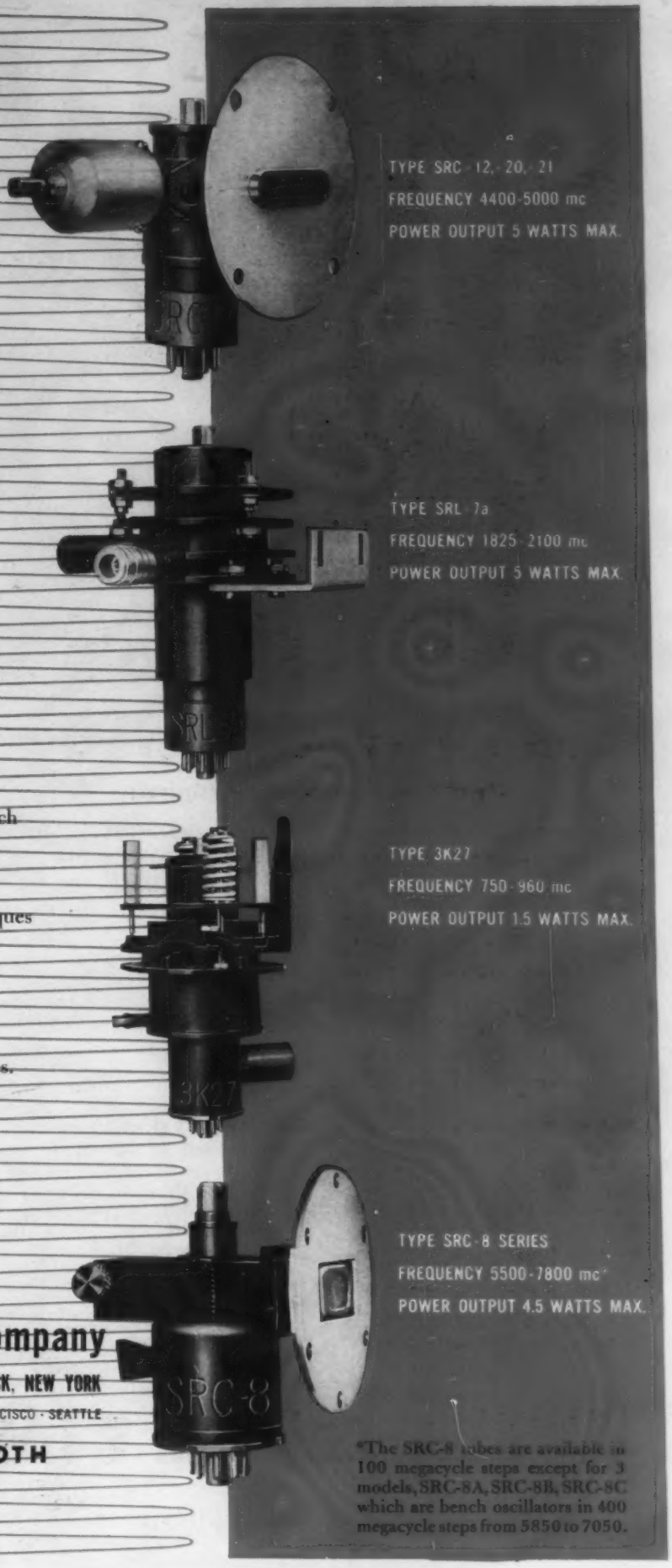
new klystron tubes

NOW AVAILABLE FOR MICROWAVE RELAYS

■ Four Sperry Reflex Klystron oscillators for microwave relay systems are now available for commercial use. These Klystrons can be used either as transmitting types or local oscillators. They can also be used in the laboratory as bench oscillators in the development of microwave relay systems.

■ With these new Klystron tubes, relay techniques are simplified and the mechanical problems associated with lower frequency relay links are overcome.

■ Other Sperry Klystrons are available in the frequency range from 500 to 12,000 megacycles. Our Industrial Department will gladly supply further information.



*The SRC-8 tubes are available in 100 megacycle steps except for 3 models, SRC-8A, SRC-8B, SRC-8C which are bench oscillators in 400 megacycle steps from 5850 to 7050.

Sperry Gyroscope Company

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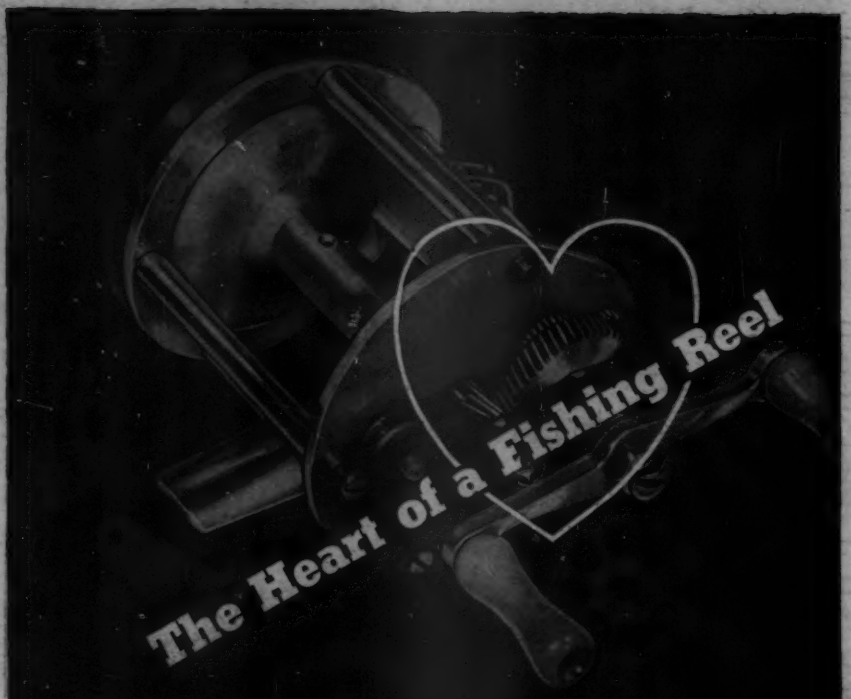

Fishing reel gears must operate smoothly at a speed of 3000 revolutions per minute or more, when a cast is executed. These gears must also withstand the strain of hauling in a fighting fish of unpredictable size and strength, thus rendering a dual purpose: speed and velvety smoothness in one direction—strength and durability in the other.

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stability, it is used as a potting compound to protect and stabilize electronic circuits.

AUTOMATIC electronically controlled machinery for high vacuum thermal evaporation of metallic salts and metals on optics, as in the production of front surfaced television projection mirrors, has been developed by National Research Corp. Glass to be coated passes on a conveyer through a series of locks to the vacuum coating chamber and then through another series returning to atmospheric pressure. The application of automatic control to high vacuum processing greatly extends its industrial significance.

Electronically controlled high vacuum evaporation equipment for coating lenses and for plating mirrors

UNIVERSAL capacitor microphone principles, details of crystal filters for communication systems, and sound recorders and reproducers developed in Germany are described in three reports available through the Office of Technical Services, Dept. of Commerce.

The capacitor microphone, used for broadcast pickups, can be constructed to have either a unidirectional, bidirectional, or nondirectional response. The microphone operates on the gradient of the sound pressure and the diaphragm is resistance controlled so that the response is independent of frequency (PB-79584, mimeograph $0.25).

Information based on an interview with Dr. Krambeer, chief filter designer of Siemens Halske Labs.,

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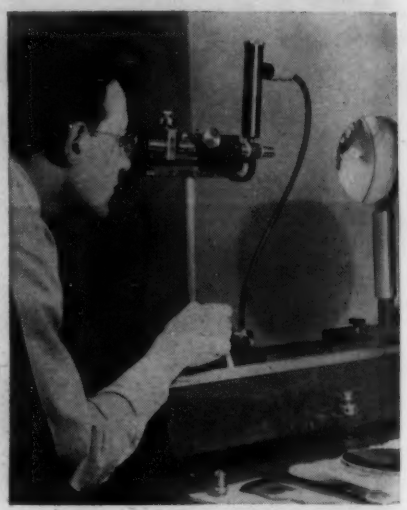
and contained in an exchange report prepared by the British Intelligence Objectives Sub-Committee describes methods of designing channel, narrow band, and low and high pass crystal filters (PB-80572, microfilm $1.00).

Electroacoustic measurements can be logarithmically recorded by techniques used in the Neumann damping recorder. The method is suitable for determining voltage differences in sound frequency generators such as receivers and microphones (PB-69125, microfilm $1.00).

CONCENTRATED ARC LAMP (ELECTRONICS, p 202, Feb. 1947) is used as a point source in projecting a wide angle beam capable of covering the large spherical mirrors used in projection television receivers.



Optical laboratory instrument paves the way for production inspection of television projection mirrors

The technique is used at North American Philips Labs. to determine means for improving quality of mirrors. The image formed is examined by the same lens system that projects the light beam.

VERY DILUTE CONCENTRATIONS of colloids and bacteria can be compared in a pulse type penetrometer developed under OSRD and Army Service Forces contracts at Northwestern University by F. T. Gucker, Jr., H. B. Pickard, C. T. O'Konski, and J. N. Pitts, Jr. The penetrometer consists of a cell through which the stream (gas or liquid)

DU MONT Type TA-124-B

Dual Image Orthicon Chain

Split-second action through quick setup and finger-tip controls; accessibility for time-saving inspection and immediate maintenance; superlative image pickup with precise electronic viewfinder checkup; handy matched units for all required power, synchronizing, amplifying and monitoring functions plus latest camera effects—such explains the popularity of the Du Mont Type TA-124-B Dual Image Orthicon Chain for studio and outdoor telecasts alike.

Whatever your telecasting plans or requirements —from modest start (Acorn Package) to most ambitious setup—whether local station or network—be sure to get the details of this oustanding camera equipment. From camera to antenna, it's DU MONT for "The First with the Finest in Television."

FEATURES...

Heavy-duty cables and "Jiffy" Connectors for trouble-free operation. Built in intercommunications.

Camera: Four-lens turret. Electronic viewfinder and camera integral assembly, but separately operable. Heater and blower for wide variation of ambient temperatures. Pan-handle operation of focus control. Remote iris adjustment from camera rear. No screwdriver controls. Factory-aligned peaking in video preamplifier.

Auxiliary: Pentode control of focus-coil current. Independent cable delay compensation for multiple camera hook-ups.

Power Supplies: Rugged construction. Super-regulating supplies for video circuits.

Control and Monitor: Thumb-wheel controls. Line-to-line clamp circuits. Single-camera chain operation if necessary.

Sync Generator: Smallest and lightest portable unit extant. Better rise time of pulses and freedom from adjustments than most studio type sync generators.

Distribution Amplifier: Equipment set up to handle up to four cameras without use of junction boxes.

Mixer Amplifier and Monitor: Automatic lap dissolve and fading circuits (four speeds) applicable up to four channels. Normal manual mixing and fading, also built in.

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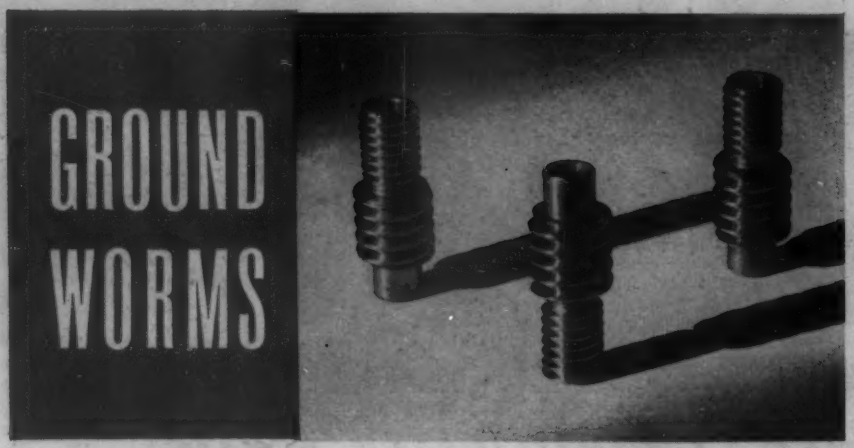

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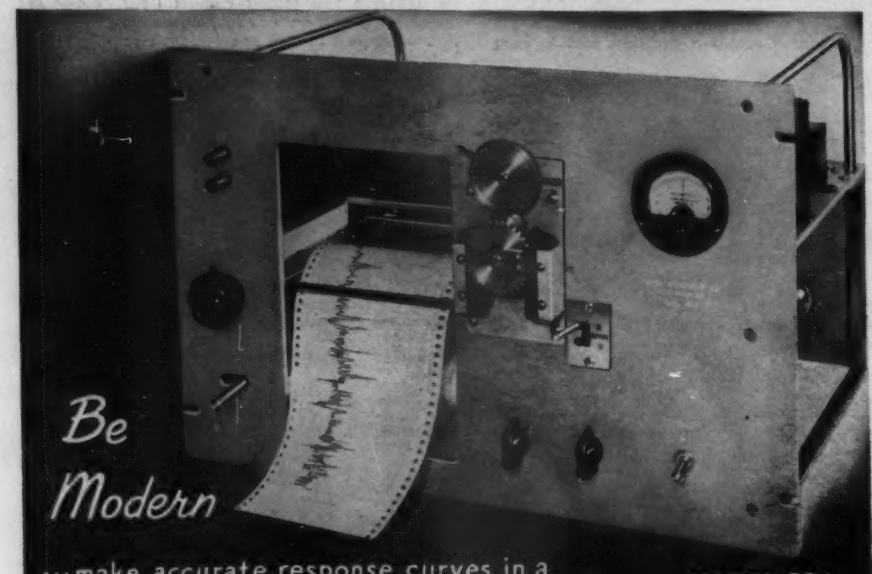

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bearing the very dilute concentration to be measured passes an intense light-beam. Particles in the stream scatter light to a thalofide cell or photomultiplier tube which feeds an amplifier having a maximum voltage gain of 300,000. As a particle passes the beam, it scatters light to the photocell for about three milliseconds. A thyratron in the amplifier output is thus operated to actuate a mechanical counter. The count over a measured time interval is indicative of the particle concentration (PB-79150, microfilm $1.).

STANDARD OF LENGTH might be made the green radiation of mercury 198, an isotope transmuted from gold by neutron bombardment. Because the human eye is more sensitive to this green line than to the red line of cadmium, used as a standard because of its greater stability and precision than the standard platinum-iridium meter bar, adjustment of interferometers with which lengths are measured is more readily done. Also this green line is stable, reproducible, sharp, and easily maintained, according to Dr. W. F. Meggers of the National Bureau of Standards.

CAPACITOR paper having densities from 1.25 to 1.30 were manufactured in Germany; highest density attained in America is 1.00. The high density paper is the result of using high-grade Finnish pulp, slow-speed paper making machines, carefully controlled wetting of the paper, and especially the final supercalendering on fine mechanical machines (mimeographed copies of 15 page PB 80394, "Supercalendering of Condenser Paper", are available from Office of Technical Services at $0.50 each.)

VOLTAGE on power lines varies—In the District of Columbia, voltages at substations vary about 4 percent, according to National Bureau of Standards measurements. Considering the greater amount of heavy industry in other districts of the country, voltage drops in mains, distribution transformers, and plant wiring, the Bureau estimates that voltages in factories vary about 11 percent.

Mica
TRANSMITTING CAPACITORS

An outstanding choice of bakelite-molded receiving and transmitting capacitors for widest range of requirements.

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Bakelite-cased potted transmitting capacitors for greater load-carrying capacity. Aerovox current ratings insure the most satisfactory selection.

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Stack-mounting heavy-duty capacitors for transmitting and other high-voltage applications.

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Ultra-high-frequency molded-in-bakelite capacitors featuring high-voltage minimum-inductance characteristics.

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Water-cooled oil-filled mica capacitors for higher KVA ratings and greatly reduced capacitor size for given power ratings.

• Be it tiny "postage-stamp" mica capacitor or large stack-mounting unit—regardless, it's a *precision* product when it bears the Aerovox name.

Only the finest ruby mica is used. Each piece is *individually gauged and inspected.* Uniform thickness means meeting still closer capacitance tolerances. Also, sections are of exceptionally uniform capacitance, vitally essential for those high-voltage series-stack capacitors. Meanwhile, the selection of perfect mica sheets accounts for that extra-generous safety factor so characteristic of ALL Aerovox capacitors.

Send us your capacitance problems . . .

Aerovox application engineering service is yours for the asking. Let us quote on your mica, paper, oil, electrolytic, ultra-high-frequency, power-factor and other capacitor needs.

FOR RADIO-ELECTRONIC AND INDUSTRIAL APPLICATIONS

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SILICONE FIBERGLAS LAMINATE

PHENOLITE
Laminated PLASTIC

Remarkable
HEAT RESISTANT
Material

PHENOLITE

Possesses these
Exceptional Properties

Tensile Strength	19,000 lbs./sq.in.
Flexual Strength	44,000 lbs./sq.in.
Compressive Strength	46,000 lbs./sq.in.
Water Absorption (1/16" thk.-24 hrs.)	0.15%
Power Factor, 10^6 cycles—Dry	0.0012
Power Factor, 10^6 cycles—(after 24 hrs. water immersion)	0.0086
Dielectric Constant, 10^6 cycles	3.90
Dielectric Loss Factor, 10^6 cycles	.0048
Insulation Resistance	71,600 megohms
Dielectric Strength	485 volts/mil
Arc Resistance (ASTM method)	228 seconds

GRADE G-7-830 Phenolite combines high heat, flame and arc resistance. It is recommended for exacting low loss electrical applications and for insulation in transformers, motors and other applications subjected to elevated temperatures.

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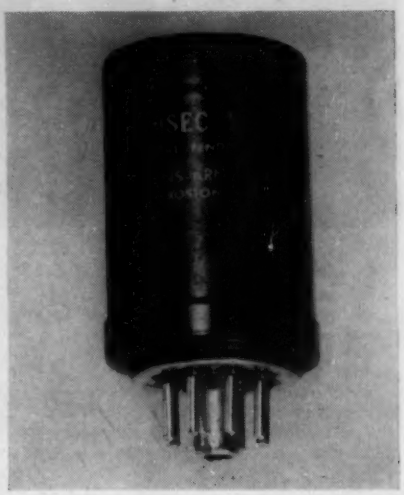
contains a microphone and a blank-cartridge gun. Sound of the initial explosion as well as the reflected pulses are picked up, amplified, and recorded.

High-Speed Relay (13)

STEVENS-ARNOLD INC., 22 Elkins St., South Boston, Mass. The new Millisec d-c relay has an operating



time as short as $\frac{1}{3}$ millisecond. It is assembled in an hermetically sealed container, with an 8-prong octal base, and made in two sizes, either single-pole, double-throw, or double-pole, double-throw.

Sync Signal Generator (14)

ALLEN B. DU MONT LABORATORIES, INC., 42 Harding Avenue, Clifton, N. J. Model TA-107 A/B synchronizing signal generator furnishes horizontal and vertical driving pulses, blanking signals, and composite synchronizing signals required by studio and film cameras, camera control units, monitors

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Chatham also designs, develops and manufactures Electronic Equipment to exact customer specifications. Inquiries regarding this service are invited.

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CHATHAM 866-A RECTIFIER

A rugged half wave Mercury Vapor rectifier to withstand high peak inverse voltages. Heavy duty filament. Fil. 2.5 volts, 5.0 amp. . . . Peak inverse anode voltage 10,000 volts, .25 amp. average anode current.

CHATHAM 394-A THYRATRON

A Mercury Vapor and Argon filled thyratron for grid controlled rectifier service . . . Amb. Temp. range of —40° C to +80° C. Heater 2.5 volts, 3.2 amp. . . . Peak inverse anode voltage 1250 volts, 640 ma. average anode current.

CHATHAM 2051 THYRATRON

An Argon filled shield grid thyratron for grid controlled rectifier service. Permits use of high resistance in grid current. Heater 6.3 volts, 0.6 amp. . . Peak inverse plate voltage 700 volts. 75 ma. average plate current.

CHATHAM 2050 THYRATRON

A Xenon filled shield grid thyratron for grid controlled rectifier service. Permits use of high resistance in grid current. Heater 6.3 volts, 0.6 amp. . . . Peak inverse plate voltage 1300 volts, average anode current 100 MA.

CHATHAM 884 THYRATRON

An Argon filled thyratron for use as a sweep circuit oscillator in cathode ray tube circuits. Stable oscillator. Heater 6.3 volts, 0.6 amp. . . . Peak forward plate voltage 300 volts, 75 ma. average plate current.

CHATHAM 4B32 RECTIFIER

A rugged half wave Xenon filled rectifier. Operates in any position throughout an ambient temperature range of —75° C to + 90° C Fil. 5 volts, 7.5 amp. . . . Inverse peak anode voltage 10,000 volts, 1.25 amp. average anode current.

CHATHAM 2D21 THYRATRON

A Xenon filled shield grid thyratron for grid controlled rectifier service. Permits use of high resistance in the grid circuit. Heater 6.3 volts .6 amp. . . . Inverse peak plate voltage 1300 volts, 100 ma. average plate current.

CHATHAM 5594 THYRATRON

Xenon filled thyratron. Operates through ambient temperatures from —55°C to +90° C without auxiliary equipment to maintain bulb temperature. Fil. 2.5 volts, 5.0 amperes. Peak inverse 5000 volts, anode current 0.5 amps, average, 2.0 amps peak.

CHATHAM 872-A RECTIFIER

A half wave Mercury Vapor rectifier to withstand high peak inverse voltages. Heavy duty filament. Fil. 5 volts, 7.5 amp. . . . Peak inverse anode voltage 10,000 volts, 1.25 amp. average anode current.

CHATHAM 885 THYRATRON

An Argon filled thyratron for use as a sweep circuit oscillator in cathode ray tube circuits. Stable oscillator. Heater 2.5 volts, 1.4 amp. . . . Peak forward plate voltage 300 volts, 75 ma. average plate current.

CHATHAM 17 THYRATRON

A Mercury Vapor thyratron for grid controlled rectifier and general application . . . rugged filamentary cathode. Fil. 2.5 volts, 5.0 amp . . . Peak inverse anode voltage 5,000 volts, 0.5 amp. average anode current.

CHATHAM 3B28 RECTIFIER

This rugged half wave Xenon filled rectifier will operate in any position and throughout an ambient temperature range of —75° C to +90° C. Fil. 2.5 volts, 5.0 amp. . . . Inverse peak anode voltage 10,000 volts, .25 amp. average anode current.

CHATHAM 1Z2 RECTIFIER

A small bulb high voltage vacuum rectifier. Low cathode heating power and low dielectric losses make tube suitable for radio frequency supply circuits. Fil. 1.5 volts, .290 amp. . . . Inverse peak plate voltage 20,000 volts, 2 ma. average plate current, 10 ma. peak plate current.

WRITE FOR CATALOG! **The informative CHATHAM catalog contains complete information and technical data covering CHATHAM rectifiers. For your free copy, write on company letterhead today.**

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PRODUCES BETTER PROFITS

by 'PINPOINTING' THE TROUBLE

- TO SPEED PRODUCTION.
- Enable Quick Correction of Rejects.
- Save Time and Money all along the production line.
- Capacity for the biggest TV chassis or the tiniest midget radio.
- Pre-tests sub-assemblies to insure final assembly operation.

USED BY MAJOR MANUFACTURERS*

HIGH SPEED INSPECTION — Checks a circuit per second. Up to 119 circuits can be checked for resistance to tolerances of 5%, 10% or 20% as required. Shorts, open circuits, incorrect wiring or resistance values are detected and located accurately by circuit number.

QUICK JOB SET-UP — The Model 1010 Rotobridge takes only about 15 minutes to set up and so may be used with great advantage on either short or long production runs.

NO SKILL REQUIRED — An unskilled operator can make precise tests to your highest engineering standards and specifications and merely 'ticket' the trouble by number for follow-up service.

PROVED PRODUCTION TOOL — The result of 5 years of development work. Now used by some of the major low-cost producers of television and radio receivers.

PRODUCTION EXECUTIVES AND ENGINEERS: Ask for descriptive literature and (if you have not already seen it) for a reprint of article entitled "*Automatic Limit Bridge for Production Testing*" from the Jan. 1948 ELECTRONICS.

See the NEW ROTOBRIDGE at the I.R.E. SHOW 3rd floor BOOTH 339

*Names on request.

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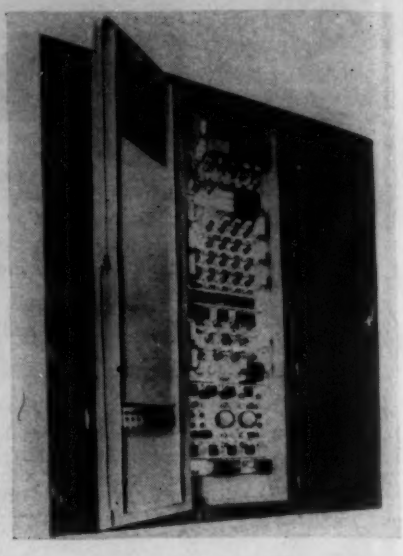


and other telecasting station equipment. Power consumption is 680 watts. Equipment conforms to all RMA and FCC specifications.

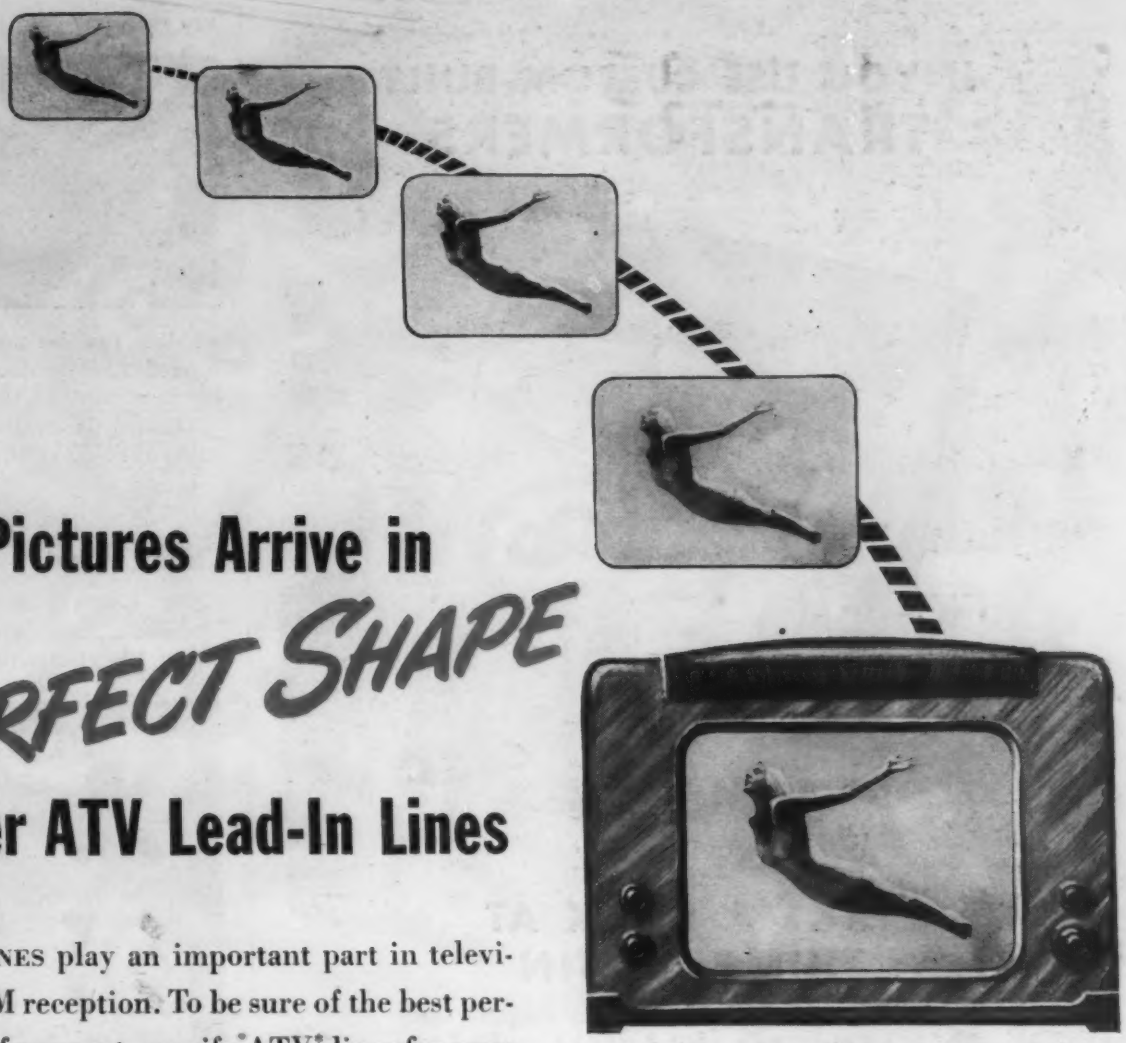
Tube and Set Tester (15)

SIMPSON ELECTRIC CO., Chicago, Ill. A new tube and set tester model 445 incorporates the well-known model 260 meter. The tube tester is the plate conductance type

with an automatic reset mechanism that returns all switches to normal at the end of each test. Sockets for all types of tubes are provided.

X-Ray Tube (16)

WESTINGHOUSE ELECTRIC CORP., Bloomfield, N. J. A small x-ray tube designed for application in selfcontained dental, portable and mobile oil-filled equipments for low current high detail radiographic work features a hooded anode and a getter. A relatively thin x-ray



The Pictures Arrive in *PERFECT SHAPE*

Over ATV Lead-In Lines

LEAD-IN LINES play an important part in television and FM reception. To be sure of the best performance of your set, specify "ATV" lines for your set.

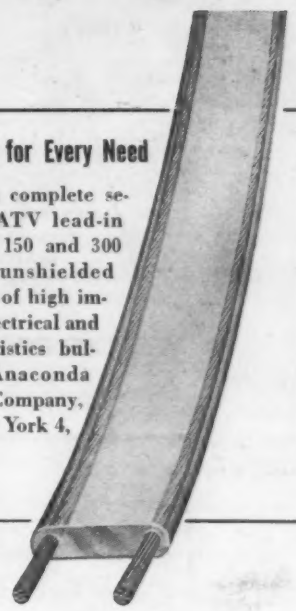
The effects of attenuation and impedance mismatch on FM and Television reception are minimized by Anaconda Type ATV lead-in lines.

The satin-smooth polyethylene insulation of Type ATV line sheds water readily, thus avoiding subsequent impedance discontinuities. This material also has exceptionally high resistance to corrosion. Count on Anaconda to solve your high-frequency transmission problems—with anything from a new-type lead-in line to the latest development in coaxial cables.

48447

A Type ATV Lead-In for Every Need

Anaconda offers a complete selection of Type ATV lead-in lines for 75, 125, 150 and 300 ohms impedance unshielded and shielded lines of high impedance. For an electrical and physical characteristics bulletin, write to Anaconda Wire and Cable Company, 25 Broadway, New York 4, N. Y.



*An Anaconda Trade-Mark

ANACONDA

Anaconda Wire and Cable Co.

25 Broadway, New York 4, N. Y.

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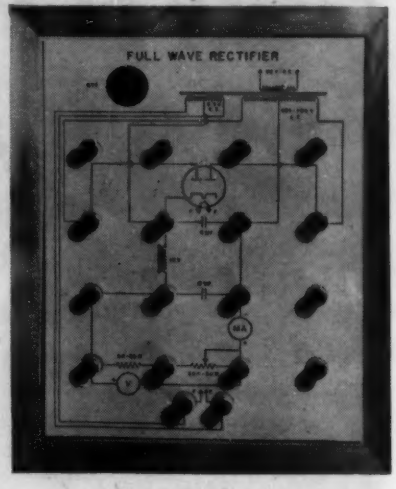
Please Rush Our Copy
Your New Special-Purpose
TRANSFORMER BULLETIN
DL-K-301 A

window can be used because the hooded anode reduces the electron bombardment of the envelope. Information is available on several tubes that make up this new line.

Circuit Panel (17)

KEPCO LABORATORIES, INC., 142-45 Roosevelt Ave., Flushing, N. Y. Model 104 electronic circuit panel,



designed for fundamental laboratory experiments, aids in investigating the characteristics of vacuum and gas-filled tubes as well as the circuits using these tubes. It contains three octal tube sockets and eighteen binding posts mounted on a panel. Supplied with the unit are 23 keyed circuit diagrams and 3 master charts.

Lab Amplifier-Suppressor (18)

HERMON HOSMER SCOTT, INC., 385 Putnam Ave., Cambridge, Mass. Type 210-A laboratory amplifier is supplied with a matched variable reluctance pickup cartridge. The amplifier has less than 2 percent distortion at 20 watts output. Below 8 watts distortion falls to under 0.5 percent. Frequency range

TIME SAVING BASIC LABORATORY INSTRUMENTS by KAY . . .

The-MEGA-MATCH

For

VISUAL DISPLAY OF REFLECTED ENERGY

- 10 to 250 MC and up. Complete television and FM coverage.
- Completely electronic. No slotted lines, moving parts, bridges, or other frequency sensitive devices such as directional couplers.
- Precision frequency meter.
- Saves engineering time—Visual display presents instantly data which would take hours to tabulate.
- Can be adapted for balanced lines.

Completely Electronic

This unique instrument presents a visual display of REFLECTED energy over any band up to 30 MC. By the use of the MEGA-MATCH it is possible to instantly observe and measure mismatches. Thus this instrument will check transmission lines, antennas, input and output impedance of amplifiers, converters, transformers, etc.

Price: $695 F.O.B. FACTORY

THE MEGA-MARKER

- Precision variable marker oscillator having a range of 19 to 29 megacycles for the television i. f. band.
- Crystal oscillator for the FM i. f. band (10.7 mc.)

A large easily read dial provides over 12 inches of calibrated scale length. Thus it may be read to accuracies of 0.02 megacycles.

Included in the MEGA-MARKER is a crystal controlled oscillator which provides accurate check points.

The MEGA-MARKER is a valuable accessory for FM and television applications of the MEGA-SWEEP and MEGA-MATCH.
For absolute stability the regulated power supply of the MEGA-SWEEP of the MEGA-MATCH is used.

Weight 5 lbs., Size 7 x 10 x 6, Price $60.00 F.O.B. factory

THE MEGA-PULSER

Recently developed instrument for generating ultra-short pulses. Its pulse characteristic (shortest pulse) is 0.05 Micro-seconds in length with a flat top of 0.03 micro-seconds duration. Impedance level 75 ohms. Pulse Amplitude is 150 volts.

The MEGA-SWEEP WIDE RANGE SWEEPING OSCILLATOR

DISPLAYS PASS BAND

Continuous frequency coverage up through the color television bands

Shows at a glance the response of any network of amplifier. Eliminates the tedious point to point analysis. Saves engineering time and stimulates research. Valuable for television production alignment.

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Testing Television Systems and Components
Testing Radar Systems and Components.
Instructional Purposes in Schools and Universities.
Designing Wide-Band i.f. Amplifiers.
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Production Testing of F. M. and Television Equipments.
As a Signal Source of Extraordinary Range (Unmatched by any existing commercial signal generator.)
As a cw high frequency oscillator.
Self-contained. Regulated, Power Supply—117 Volt 60 Cycle. Operation—Size 9" x 17" x 11"—Weight 35 Pounds.

FEATURES

CARRIER FREQUENCY
50 kilocycles to 500 megacycles & up.
FREQUENCY SWEEP
From 30 Megacycles to 30 kilocycles throughout the complete spectrum.
CONTINUOUSLY VARIABLE ATTENUATOR
LOW AMPLITUDE MODULATION WHILE SWEEPING
Less than 0.1 DB per megacycle.
PRECISION WAVEMETER

Price $395 F. O. B. Factory

THE MEGA-PIPPER

The MEGA-PIPPER is a new production and service alignment instrument. By the use of this unit in conjunction with the MEGA-SWEEP or MEGA-MATCH it is possible to quickly and accurately align television receivers.
The MEGA-PIPPER gives four precise crystal controlled pips which are independent of the circuit under test. These pips establish the picture, sound carrier, and also the adjacent channel points. Thus the MEGA-PIPPER is an instrument which will save many hours of time spent in alignment. No switching or adjustment is necessary for frequency control.
Inasmuch as the pips are fed directly into an oscilloscope the pips are visible at all times, even in the traps where the highest precision is desired.
Self contained power supply.
Weight 15 lbs. Size 8 x 16 x 8. Price $150. F.O.B. factory.

KAY ELECTRIC COMPANY

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More EFFICIENCY APPLICATIONS VALUE

by using these NEW RACON SPEAKERS and HORN UNITS

Right — NEW RADIAL RE-ENTRANT SPEAKER, excellent for all types of industrial sound installations, provides superlative and complete 360° speech intelligibility by efficiently over-riding factory high noise levels. Frequency response 300-6000 cps. Handling capacity 25 watts continuous, 35 w. peak. Has mounting bracket. Size 12" wide by 12 5/8" high.

Left — NEW SMALL RE-ENTRANT HORNS, extremely efficient for factory inter-com and paging systems; for sound trucks, R. R. yards and all other industrial installations where high noise levels are prevalent. Watertight, corrosion-proof, easily installed. Two new models—type RE-1 1/2, complete with Baby Unit, handles 25 watts, covers 300-6000 cps; type RE-12, complete with Dwarf Unit, handles 10 watts, has freq. response of 400-800 cps.

Right—NEW SPECIAL PM HORN UNIT, having Alnico V magnet ring completely watertight, housed in a heavy aluminum spinning. Provides extremely high efficiency reproduction with minimum input. Handling capacity 35 watts continuous, 60 w. peak.

To the more than 60 different type and size speakers and horn units that already comprise the RACON line—these new models have been added. There is a RACON speaker and horn unit ideal for every conceivable sound system application. RACON has not only the most complete line, but also has the most preferred line. For over 20 years leading Soundmen have recognized and specified them because of dependability, efficiency and low-cost, and because the reproducers are trouble proof.

RACON ELECTRIC CO., INC.

52 E. 19th St., New York 3, N. Y.

RACON

Write for catalog describing RACON'S Line of Horns, Speakers, Units, Accessories, Inc.

exceeds 20,000 cycles and with dynamic noise suppressor response is flat to 10,000 cycles. Bass and treble tone controls are provided. For a-m reception a whistle filter can be switched in.

Radiation Meter (19)

VICTOREEN INSTRUMENT CO., 5806 Hough Ave., Cleveland 3, Ohio. The portable 247A gamma ray survey meter is the ionization chamber

type that is hermetically sealed and watertight. Four ranges of sensitivity are provided to allow full-scale readings of 2.5, 25, 250, and 2,500 milliroentgens per hour. Total weight of the rugged instrument is 11¾ pounds.

Wire-Wound Resistors (20)

CLAROSTAT MFG. CO., INC., 130 Clinton St., Brooklyn, N. Y. announces the Greenohm Juniors, ceramic-cased midget wire-wound resistors for small spaces and for facilitating point-to-point wiring. Standard type C7GJ is rated at 7 watts,

LISTED UNDER REEXAMINATION SERVICE UNDERWRITERS' LABORATORIES, INC. UL

...mean 105°C continuous operating temperature

A *NEW HIGH* FOR EXTRUDED VINYL TUBING

Natvar 400 now has "four ridges equally spaced around the circumference, and running the length of the tubing." This marking was specified by Underwriters' Laboratories to distinguish it from tubings limited to lower temperatures.

It may now be safely used in many applications instead of varnished sleeving, with great savings in material and labor costs and reduced waste.

More and more users of extruded tubing are standardizing on Natvar 400 because, in addition to its remarkable heat and oil resistance, it is well balanced in other properties. E. T. L. and Underwriters' reports are available on request.

Natvar

Natvar Products

- Varnished cambric—straight cut and bias
- Varnished cable tape
- Varnished canvas
- Varnished duck
- Varnished silk
- Varnished special rayon
- Varnished Fiberglas cloth
- Silicone coated Fiberglas
- Varnished papers
- Varnished tubings and sleevings
- Varnished identification markers
- Lacquered tubings and sleevings
- Extruded vinyl tubing
- Extruded vinyl identification markers

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Are you using modern methods and equipment for marking the products you manufacture? Right now Noblewest Rapid Production Marking Machines are stepping up production and saving money for leading manufacturers of electronic products and their component parts. For example, Model No. 246, shown above, is tooled for marking GE capacitors. The inscription, shown at right, being permanently *rolled in*, lasts as long as the product itself. Noblewest equipment can be used for marking metal, plastic, hard rubber, etc. Marking speeds are practically unlimited. Every Noblewest Marking Machine is engineered to meet your specific requirements, and backed by the skill, experience and facilities of the world's leading manufacturer of rapid production marking equipment. Whatever your marking problem, Noblewest engineers will be glad to make time and money saving recommendations without obligation to you. A copy of our new catalog on Modern Marking Methods will be sent upon request. Write to Noble & Westbrook Manufacturing Company, 27 Westbrook Street, East Hartford 8, Conn.

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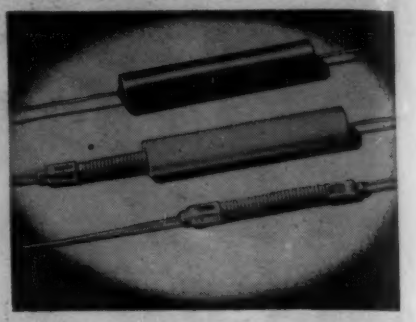
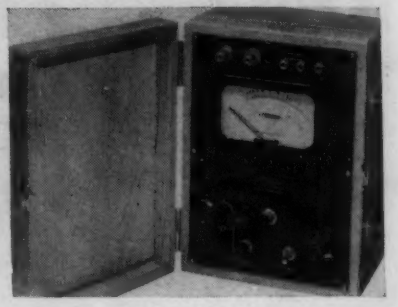
EQUIPMENT FOR MARKING · GRADUATING · EMBOSSING · NUMBERING



and is available in values from practically zero to 5,000 ohms maximum; smaller type C4GJ is rated at 4 watts, with maximum resistance of 1,000 ohms.

Log Scale Megohmmeter (21)

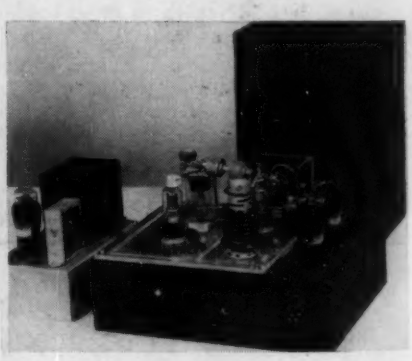
MACLEOD & HANOPOL, Charlestown 29, Mass. Logarithmic scale dis-



tribution of this direct-reading megohmmeter gives the same accuracy over the whole range of 1 to 100,000 megohms, covered by six decade steps. Range can also be extended to 1,000,000 megohms.

Projection Television Components (22)

SPELLMAN TELEVISION CO., 2898 Jerome Ave., New York 58, N. Y. The 30 kv r-f power supply illustrated has a low voltage supply separate from the high voltage pack. Voltage can be varied from



.022 .0047 .15 .033 .068

Funny Numbers?

. . . perhaps, but they are more evidence of SPRAGUE LEADERSHIP!

New Phenolic-Molded Sprague Tubular Capacitors Produced in Decade Ranges and Color-Coded!

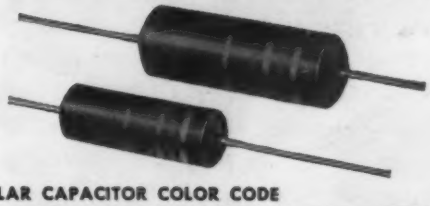
With the recent introduction of its sensational new *molded* tubular capacitors, Sprague now announces standardized capacities, and color-coding for ready identification of these new units. For example, starting with the number 1, the next numbers in the 20% tolerance decade are 1.5, 2.2, 3.3, 4.7, 6.8 and on back to 10.

Established decade ranges and color-coding have proved their efficiency and acceptability in the resistor industry over a period of years. Now, for the first time, this same practice will allow capacitor manufacturers the many advantages of standardized production—advantages which we feel will be cumulative through the years.

In the firm conviction that these steps toward standardization will prove mutually beneficial, Sprague Electric Company solicits your cooperation and invites your inquiries for information, samples and application data concerning the new SPRAGUE MOLDED TUBULAR CAPACITORS. WRITE FOR ENGINEERING BULLETIN NO. 210A.

THE FIRST TRULY PRACTICAL PHENOLIC-MOLDED PAPER TUBULAR!

Highly heat- and moisture-resistant • Non-inflammable • Conservatively rated for —40°C. to 85°C. operation • Small in size Completely insulated • Mechanically rugged Moderately priced.



SPRAGUE MOLDED TUBULAR CAPACITOR COLOR CODE

			Black	Brown	Red	Orange	Yellow	Green	Blue	Violet	Gray	White
1st BAND	Capacity in MMFD	First Significant Number	0	1	2	3	4	5	6	7	8	9
2nd BAND		Second Significant Number	0	1	2	3	4	5	6	7	8	9
3rd BAND		Decimal Multiplier			100	1000	10,000	100,000				
4th BAND	TOLERANCE		±20%			±30%	±40%	±5%				±10%
5th BAND	RESERVED FOR ARMED SERVICES											
6th BAND	Voltage in Hundreds (x 100)	First Significant Number	0	1	2	3	4	5	6	7	8	9
7th BAND		Second Significant Number	0	1	2	3	4	5	6	7	8	9

SPRAGUE ELECTRIC COMPANY North Adams, Mass.

CAPACITORS **SPRAGUE** *KOOLOHM RESISTORS

*Trademark reg. U. S. Pat. Off.

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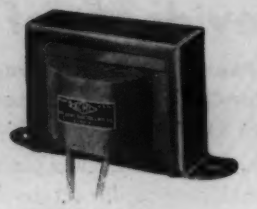
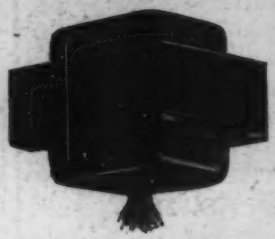
The special physical design or special electrical characteristic transformers you may need can probably be engineered from Acme Electric standard laminations and parts to the exact mechanical dimensions and electrical performance required. No need for special dies, tools or other expensive production materials. Here are a few of the Acme Electric designs available.

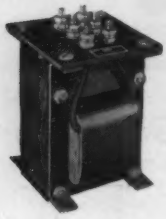


Mounting type 100. Available in ratings from 3 to 40 VA.



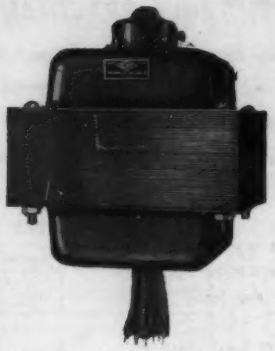
Mounting type 110. Available in ratings from 35 to 2500 VA.

Mounting type 130, 2 hole horizontal mounting lead holes on bottom or side of shell. Ratings 15 to 100 VA.



Mounting type 121. Available in ratings from 35 to 2500 VA. Taps to suit your needs.

Mounting type 131 with end bells. Leads out bottom or side. Ratings 35 to 500 VA.



Mounting type 150. 4 hole horizontal mounting. Lead holes on bottom or side of shell. Primary tap changer on top. Ratings 35 to 500 VA.

Write for Specification Transformer Bulletin 168.

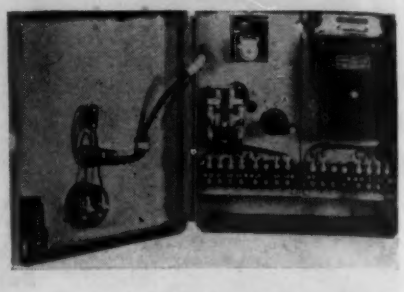
ACME ELECTRIC CORPORATION
31 WATER STREET + + + CUBA, N. Y.

Acme ACME Electric

12 to 40 kv. A focus control is provided for use with type 5TP4 projection tube. Other components include projection lens, movable stand for equipment, and a number of screens.

Combustion Control (23)

GENERAL ELECTRIC CO., Schenectady 5, N. Y. A new photoelectric



combustion control system for commercial oil burners comprises master, phototube, and electrode units. The system shuts off fuel flow immediately if oil fails to ignite or if the flame is extinguished after successful ignition. Write for bulletin GEA 4779.

Voltage Reference Tube (24)

RADIO CORP. OF AMERICA, Harrison, N. J. Type 5651 miniature glow-discharge tube maintains a d-c operating voltage of 87 volts, and has an operating current range of 1.5 to 3.5 milliamperes. Operating

characteristics are essentially independent of ambient temperature. Complete information is contained in a reference sheet.

Hand-Desk Mike (25)

ASTATIC CORP., Conneaut, Ohio. Model 200 crystal microphone has a smooth frequency response from 30 to 10,000 cycles; model 241 is similar in range but with a rising characteristic between 1,500 and

Typical insulators produced by Alsimag at very low cost

IN SOME INSTANCES

ALSIMAG

TRADE MARK REGISTERED U.S. PATENT OFFICE

INSULATORS ARE

lowest in cost

Some types of insulators can be produced by Alsimag at very low cost. Our files show many instances where Alsimag insulators are used simply because they are the lowest cost insulators that will do the job.

This comes as a surprise to many engineers and purchasing agents. They know that Alsimag materials are expensive, that Alsimag parts have dimensional accuracy and uniformity which facilitates assembly, that Alsimag has great mechanical strength, permanent rigidity, that it will not char or form electrical conduction paths and that it has a far greater dielectric efficiency than most insulating materials. Therefore it is natural that they would think that Alsimag components would be more expensive...However, in some instances, the greater cost of the Alsimag materials is more than offset by production savings. Certain sizes and designs, usually small and relatively simple shapes, are produced in quantity on automatic production equipment at such low production cost that the final price is highly competitive. Many materials commonly regarded as "cheap" are actually more expensive in first cost because those cheap materials do not lend themselves to economical manufacturing processes.

This advertisement is not an announcement of "bargain" prices. The Alsimag price structure remains unchanged. It is simply a statement of fact and an invitation to submit your insulator problems to Alsimag for cost and design analysis. You may be surprised to find Alsimag production efficiency enables you to buy superior insulators at a price competitive with materials which you have always thought of as "cheap."

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Sensational "MIDGET" PHOTO CELL THAT DOES A GIANT'S JOB

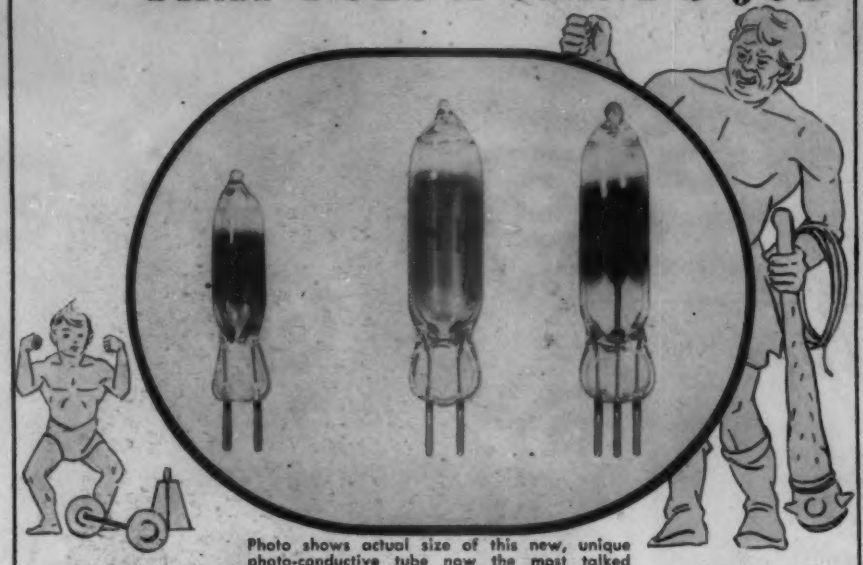


Photo shows actual size of this new, unique photo-conductive tube now the most talked about item in the tube industry.

ADVANTAGES

★ Miniature and sub-miniature sizes available.
★ Infra-red sensitivity up to 3 Mu
★ Better frequency response
★ Technical perfection, plus steady performance

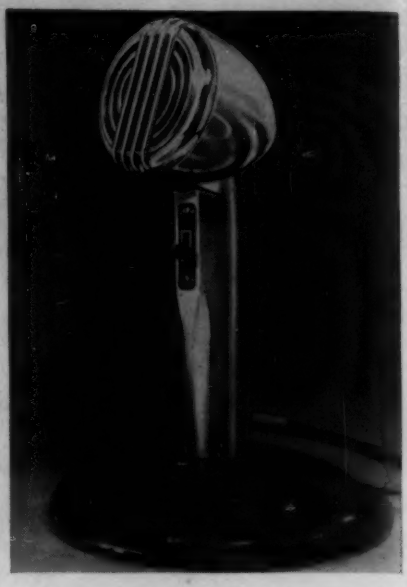
CONTINENTAL'S new lead sulphide cell is the most revolutionary development ever accomplished in photo cell manufacturing history. Nothing like it has ever been successfully advanced before. Ultra compact—it's the smallest, practical tube ever made. Continental now offers it on a straight production schedule, the consistent high quality of each tube being positively assured. You can use this exclusive Continental item with much less supplementary equipment. It will mean a large economy because you save greatly on space and materials. This "Mighty Midget" does work comparable with tubes 3 and 4 times its size with no sacrifice in high response or sensitivity. Our engineers are ready to tell you how this "Mighty Midget" can go to work for you. Wire or write us today.

Continental leadership in the photo tube field has been acknowledged far and wide. Manufacturers of Top Notch Motion Picture Sound Equipment, Coin Operated Devices, Electronic Toys, Counting Devices, Automatic Pilots for Aeroplanes and Boats, Burglar Alarms, Fire Detection Apparatus and others have perfected their machines and kept operations smooth and consistent with Continental's highly engineered tubes. We are interested in the unusual and difficult and will welcome a challenge on your own tube problem.

CONTINENTAL ELECTRIC CO.

World's Leading Single Manufacturer of Photo Cell Tubes and Electronic Specialties

GENEVA, ILLINOIS



5,500 cycles. Either model supplied with or without switch has a quick-lock base so that it can be used as hand or desk mike or mounted on a floor stand.

10-Kw R-F Generator (26)

WESTINGHOUSE ELECTRIC CORP., 306 Fourth Ave., Pittsburgh 30, Pa. Designed specifically for the woodworking industry, the new 10-kw r-f generator operates semi-automatically. A single front panel control allows adjustment for large changes in electrode size. The generator is available in 5 and 13.6-mc units that operate on 230 or 460 volts, three-phase, 60-cycle current.

Modulator Unit (27)

BEE-BEE ELECTRONIC CO., 2692 W. Pico Blvd., Los Angeles 6, Calif. The model 500 narrow-band f-m modulator unit is a reactance type designed for direct coupling to the

MEASURE SONIC FREQUENCIES . . .

INSTANTLY . . . ACCURATELY . . . VISUALLY

WITH Stroboconn

Used effectively in industrial laboratories for checking the speed of rotating objects and for calibrating or checking tachometers, measuring natural frequencies, and calibrating oscillators, impulse generators and similar equipment. With the Stroboconn, you can speed up the job with full assurance of accurate results.

A Notable Achievement in Sonic Research

The Stroboconn is essentially a logarithmic frequency meter of the Stroboscopic type, having an accuracy of frequency determination of 0.05%, in the continuous range of 32 to 4070 cycles per second. Ultra-sonic frequencies may be reduced to Stroboconn range by use of a frequency divider. The logarithmic scale is particularly advantageous in measuring ratios of two frequencies, with or without regard to the actual frequencies involved.

In use, the quantity to be measured is converted into an audio signal, amplified and fed to a discharge tube that produces flashes of light at the audio rate involved. A dial reading indicates the frequency of the input signal. Send for *free* folder and further information concerning the Stroboconn's adaptability to your particular problem.

PROVED PERFORMANCE

Among Stroboconn users are Harvard University, Bell Aircraft Corp., and Hamilton Standard Propellers. During the War, this instrument was used as a standard for checking equipment in the Army Air Forces Power Plant Laboratory, at Wright Field.

★ ★ ★

Send for Free Folder

Gives more complete information about operation and application of this amazing precision instrument. No obligation.

CONN BAND INSTRUMENT DIVISION

C. G. CONN LTD., DEPT. 312
ELKHART, INDIANA

Stroboconn

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Present 3 clean-cut Advantages

1. EXTREME UNIFORMITY
2. SUPERIOR STAKING QUALITIES
   . . . ends will roll without splitting.
3. BETTER FOR MOLDED PARTS
   . . closed end keeps compound out.

If you use pins for vacuum tubes, adapters, fluorescent lamps, plugs, or electrical equipment of any kind, the chances are you'll save time, money and rejections by using these super-smooth, *seamless,* patented Radio Pins. They are available in a wide variety of styles and sizes, with staking end either closed or open. For a quotation, simply send a sketch, sample or description and state the quantity you need.

Radio or Radar Equipment?

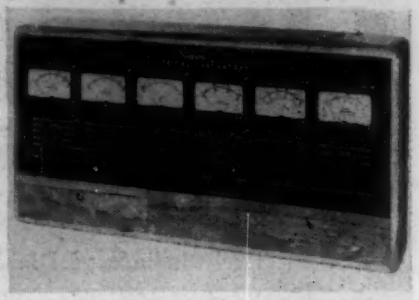
In addition to Radio Pins, we produce large quantities of top caps, base shells and adapter shells for vacuum tubes; also a wide variety of other metal products including deep drawn shells and cups, blanks and stampings, ferrules, grommets, washers, vents, fasteners—and, for almost every manufacturing requirement, the world's largest assortment of eyelets. 47420

THE AMERICAN BRASS COMPANY
Waterbury Brass Goods Branch
General Offices: Waterbury 88, Connecticut
Subsidiary of Anaconda Copper Mining Company
In Canada: ANACONDA AMERICAN BRASS LTD., *New Toronto, Ont.*

vfo or crystal socket of a conventional crystal-controlled pentode or triode oscillator.

Multi-Purpose Tester (28)

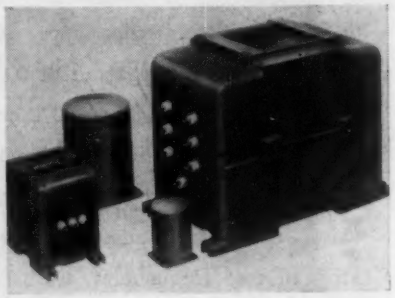
SIMPSON ELECTRIC CO., Chicago, Ill., announces the new model 1005 Electrical Laboratory, a test unit combining the functions of over 60



separate instruments. It is adaptable for testing all electrical appliances, small motors, circuits, radio sets and the like. Size is approximately 34 × 17 × 9 inches; and weight, 37 lb.

Transformers (29)

UNITED TRANSFORMER CORP., 150 Varick St., New York 13, N. Y. A



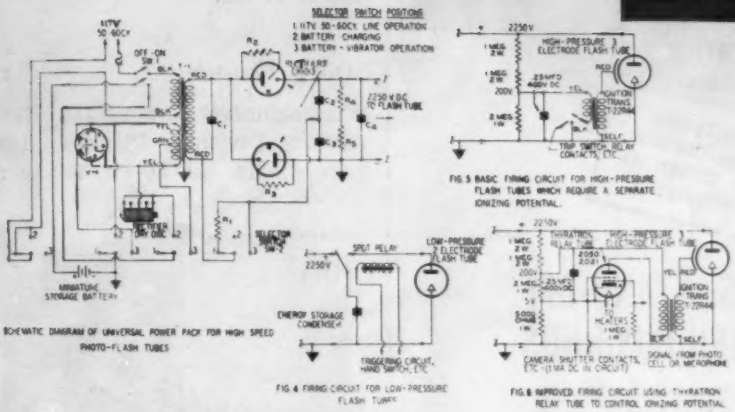
new series of commercial grade transformers includes audio components, input transformers, modulation, power, and filament transformers. They are fully described in catalog PS-408.

Dielectric Heater (30)

SHERMAN INDUSTRIAL ELECTRONICS CO., INC., 503 Washington Ave., Belleville 9, N. J. Sieco heater type SD-15 for heating plastic preforms, drying cloth, or setting glue has a

THORDARSON

DEPENDABILITY AND VERSATILITY FOR INDUSTRY



SCHEMATIC DIAGRAM OF UNIVERSAL POWER PACK FOR HIGH SPEED PHOTO-FLASH TUBES

FIG. 5 BASIC FIRING CIRCUIT FOR HIGH-PRESSURE FLASH TUBES WHICH REQUIRE A SEPARATE IONIZING POTENTIAL.

FIG. 4 FIRING CIRCUIT FOR LOW-PRESSURE FLASH TUBES

FIG. 6 IMPROVED FIRING CIRCUIT USING THYRATRON RELAY TUBE TO CONTROL IONIZING POTENTIAL

PHOTO FLASH POWER SUPPLY

Here is another Thordarson FIRST... a typical example of Thordarson engineering skill that has helped established leadership in the field. This circuit features:

- **A.C. Line or Portable Battery Operation**
- **Charging Time — 10 to 15 Seconds**
- **A.C. Line Battery Recharge Feature**
- **Light Compact Low Drain Power Transformer**
- **Power Supply Output — 2250 V.D.C.**
- **Storage Condenser Delivers 75 Watt-Sec. Energy Element**
- **Adaptable Trigger Circuits for 2 or 3 Tubes**
- **Cold Cathode Rectifiers Employed in a Voltage Doubling Circuit**

OUR ENGINEERING STAFF IS AVAILABLE TO SOLVE YOUR PROBLEMS FOR YOU UPON REQUEST

Whatever your position in the field of electronics Thordarson can serve you better. Our large variety of stock types fill almost every need. For extraordinary conditions, send us your problems and our engineering staff will come up with the right answers.

1. LOW VOLTAGE - LOW CURRENT
2. LOW VOLTAGE - HIGH CURRENT
3. HIGH VOLTAGE - HIGH CURRENT
4. HIGH VOLTAGE - LOW CURRENT

WHERE QUALITY IS A NECESSITY...

Thordarson has the answers to many electrical problems that daily confront industry. With a background of over 25,000 active specifications in their files, built up over 53 years of leadership in the field, Thordarson supplies the leaders with their large variety of stock types of transformers as well as the hundreds of special types built to customer specifications or resulting from recommendations of our own engineers upon studying the various requirements submitted to them by industry.

With this background, you know that your Thorardson equipment, purchased from stocks of a jobber or directly under special specifications, is of top-notch quality — sure to deliver unmatched performance. If you require the best, there is no unit either too large — or too small that Thordarson can't deliver.

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AMPHENOL TUBE MOUNTS, STAND-OFF INSULATORS AND FEED-THRU BUSHINGS

Amphenol tube mounts and stand-off insulators efficiently mount Thyratron 173, and similar metal industrial electron tubes, on non-insulated surfaces. Secure mounting and highest quality insulation are assured.

The use of steatite dielectric guarantees excellent heat resisting qualities, low-loss and high mechanical strength. Surface creepage distances of 2" safely accommodate high voltages. Exposed portions of stand-offs are glazed to facilitate cleaning in dusty industrial plants.

Types with steatite feed-thru bushings allow wiring back of the supporting panel. Additionally, these insulators serve as tie points, or feed-thru insulators, for tube element connections, or for passage of high voltage circuits through panels or compartment walls. Complete electrical, mechanical and pricing data immediately available on request. Write for it today.

AMPHENOL

THESE FEATURES ASSURE TOP PERFORMANCE
- Mounts in small panel area
- Adequate clearance between tube and panel permits cooling by convection
- Wing nut connections simplify assembly and wiring maintenance
- Steatite dielectric

Amphenol tube mounts and stand-off insulators are designed for use with the following metal tubes: GL-414, FG-172, FG-280, FG-190, FG-166, ELC16J, EL60B, ELI6F.

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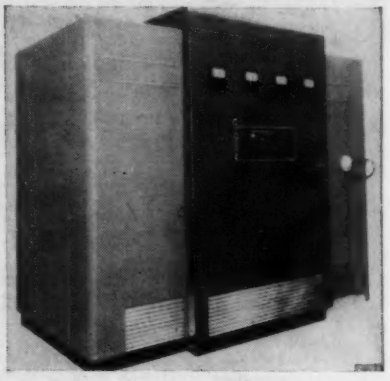
1830 S. 54th AVE., CHICAGO 50, ILLINOIS
COAXIAL CABLES AND CONNECTORS • INDUSTRIAL CONNECTORS, FITTINGS AND CONDUIT • ANTENNAS • RADIO COMPONENTS • PLASTICS FOR ELECTRONICS

continuous output of 15 kw and features pushbutton operation. No tuning or other manual adjustments are required. Frequency of operation is 27 mc.

50-kw Heater (31)

WESTINGHOUSE INDUSTRIAL ELECTRONICS DIVISION, Plant 4, Baltimore 3, Md. A 50-kw 450-kc r-f



generator and two-position work table are available for production heating jobs such as hardening gears and automotive parts. The generator operates on 230/460 volt 3-phase, 60-cycle current.

Variable Speed Motor (32)

GUERNET ELECTRICAL MACHINERY, INC., Box 196, Meriden, Conn. Designed to maintain constant maximum torque at all speeds, a new motor with ⅓ hp rating is variable from 1,500 to 6,000 rpm. A lever at the side of the motor stops and starts the motor and mechanically

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You would find it hard to set a requirement on Arnold magnets that is not already exceeded in our regular production procedure.

All Arnold products are made on a basis of 100% quality-control at *every* step of manufacture. These rigidly maintained standards cover all physical, magnetic and metallurgical characteristics. . . you can place complete confidence in the uniformity and dependability of Arnold Permanent Magnets, and their resultant performance in your assemblies.

Remember, too, that Arnold's service covers all types of permanent magnet materials, any size or shape of unit, and any field of application. Our engineers are at your command—write us direct or ask any Allegheny Ludlum representative.

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Application

90811

90811 HIGH FREQUENCY RF AMPLIFIER

The No. 90811 RF Amplifier is the same unit as used in the No. 90810 complete 2–6–10–20 meter Ham Band crystal controlled transmitter. Can be panel or base mounted. Uses 8298 or 3E29 tube with normal 75 watt output. (Higher output may be obtained by the use of forced cooling.) Provisions are made for quick band shift by means of the new 48000 series high frequency plug-in coils. Extremely compact. Chassis 4" x 7¾" exclusive of flanges. Over-all height 6¾".

JAMES MILLEN MFG. CO., INC.

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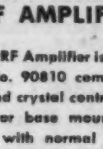
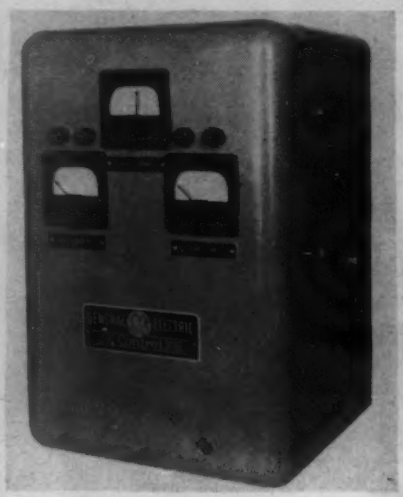
MALDEN
MASSACHUSETTS



controls a pair of centrifugal vibrating contacts that accomplish the speed variation.

Control Unit (33)

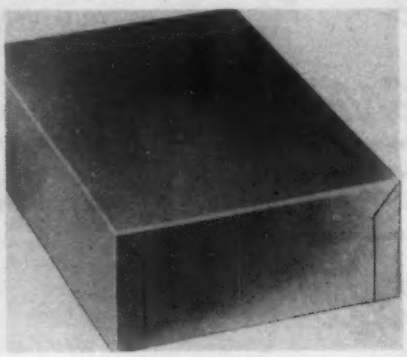
GENERAL ELECTRIC CO., Schenectady 5, N. Y. A new packaged amplidyne control unit for applications



where speed, current, or voltage regulation are required is now available. Indicating instruments are provided for ease in adjustment.

New Chassis (34)

E. F. JOHNSON CO., Waseca, Minn. A new line of chassis is so formed that no overlaps occur at the cor-



ners. The feature permits locating holes for volume controls and toggle switches all the way up to the corners. Rigidity is insured by welded tie bars on the inside of the turned under bottom edge.

Servicing CRO (35)

HICKOK ELECTRICAL INSTRUMENT CO., 10527 Dupont Ave., Cleveland

precision-fabricated PLASTIC PARTS

QUALITY and SERVICE AT A PRICE THAT'S RIGHT

With more and more manufacturers switching to plastic parts to improve the appearance and performance of their products, it is significant that so many look to Sillcocks-Miller for the quality and service they want. This organization of specialists is recognized throughout the industry for its skill in fabricating plastic parts to close tolerances and its reputation for unvarying quality. With complete facilities to meet your requirements . . . no matter how large or small . . . Sillcocks-Miller offers you the dependable source you want for plastic parts and service, at a price that's right.

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30 West Parker Avenue, Maplewood, N. J.
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SPECIALISTS IN HIGH QUALITY, PRECISION-MADE PLASTICS FABRICATED FOR COMMERCIAL, TECHNICAL AND INDUSTRIAL REQUIREMENTS.

PLASTICON HIVOLT SUPPLIES

High Voltage - Low Current DC Power Supplies

for

Television—Radiation Counters—Photoflash Devices—Electrostatic Precipitators—Spectrographic Analysers, Oscilloscopes, Etc.

HiVolt Supplies are self-contained in hermetically sealed metal containers. They are designed to transform low voltage AC to high voltage - low current DC.

HiVolt PS-1

Specifications:

Volts Input: 118 VAC, 60 cycles.
Volts Output: 2400 VDC (capacitor load)
Current Output: .006 Amps., half-wave DC.
Max. Watts Input: 15 watts.
Type of Filter: Net filtered.
Terminals: 8-32 screw and nuts.
Insulation: 118 VAC—2 bakelite washers;
2400 VDC—1 porcelain standoff;
2400 VDC—lug spotwelded to case.
Container: Terne plate steel—gray lacquer finish.
Size: 3¾" x 3 3/16" x 5½".
Weight: 2.2 lbs.

List Price $18.95 F. O. B. Chicago

NOTE: The PS-1 is designed to charge a parallel-wired bank of not more than 15 AOCOE-22C3 Plasticon Energy Storage Capacitors (48 mfd.).

HiVolt PS-2

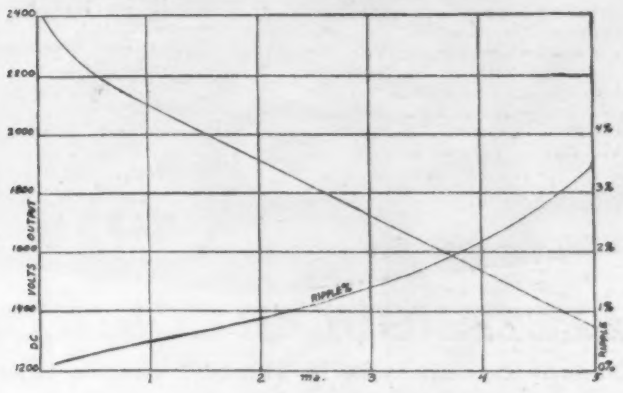
Specifications:

Volts Input: 118 VAC, 60 cycles.
Volts Output: 2400 VDC, maximum.
Current Output: .005 Amps. DC. maximum.
Max. Watts Input: 10 watts.
Type of Filter: R. C. Filter: 50,000 ohms, 2x.1 mfds.
Terminals: 8-32 screw and nut.
Insulators 118 VAC—2 bakelite washers;
2400 VDC—2 porcelain standoffs;
container neutral.
Container: Terne plate steel—gray lacquer finish.
Size: 3¾" x 3 3/16" x 5½".
Weight: 2.5 lbs.

List Price $25.75 F. O. B. Chicago

NOTE: The PS-2 is similar in appearance to the PS-1 except that all four terminals are on the recessed top of the container.

Regulation and Ripple Curves



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Over 25 years experience in the manufacture of specials at cost that compares favorably with standard types. Built-in quality proved by years of actual use.

From 10VA to 300 KVA Dry-Type Only, Both Open and Encased, 1, 2, & 3 Phase 25 to 400 Cycles.

PROMPT DELIVERIES!

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WINDING LABORATORIES
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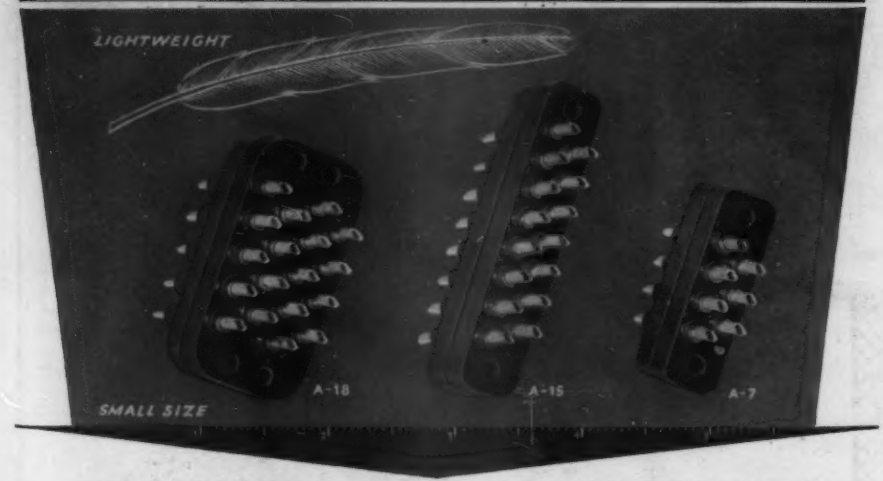
WINCHESTER ELECTRONICS

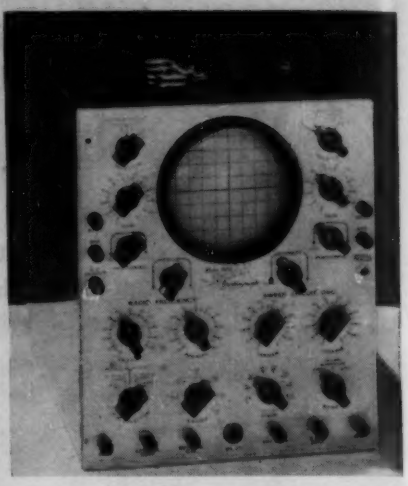


RECTANGULAR CONNECTORS

Currently available with 18, 15 and 7 contacts, these lightweight connectors are designed for a minimum of weight and size while retaining typical WINCHESTER features such as MONOBLOC* construction, melamine insulation, precision machined contacts and long creepage paths. Strain relief cable clamps available. Send for Bulletin A.

*Trademark

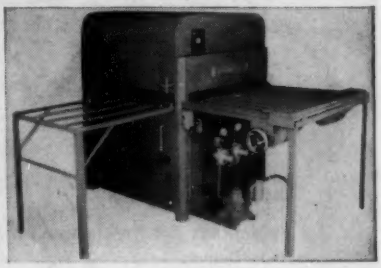
WINCHESTER ELECTRONICS COMPANY 6 East 46th Street, New York 17
FORMERLY THE WINCHESTER CO.



8, Ohio. Model 505 cathode-ray oscilloscope has been designed for the visual analysis of receiver circuits and the signal-tracing technique in trouble shooting. The equipment generates an f-m signal so that it can be used for aligning i-f and r-f transformers and discriminator circuits.

H-F Gluing Machine (36)

ELECTRONIC HEATING ASSOCIATES, 75 Jefferson St., Newton 58, Mass. The new high-frequency glueing



machine for woodworking, called Raybond, has a capacity from 400 to more than 1,200 square feet of edge-bonded blanks an hour. It requires only one operator and accommodates stock in thicknesses from $\frac{5}{8}$ inch to 2 inches with adjustable pressure as required. Average complete work cycle takes from 20 seconds to one minute. Several models are available.

Time Switch (37)

PALO-MYERS, INC., 81-83 Reade St., New York 7, N. Y. The new time switch for laboratory and industrial uses is a selfcontained unit incorporating equipment for turn-

EAD

FRACTIONAL H.P. MOTORS

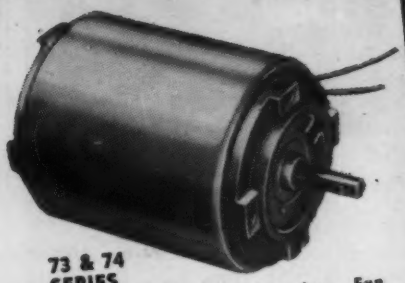
BLOWER UNITS

CONTROL COMPONENTS

73C & 74C SERIES

115-220 Volts—50, 60 and 400 cycles . . . Continuous duty. Sleeve Bearing . . . Fan Cooled . . . Totally Enclosed. Outside Diam. 3⅞".

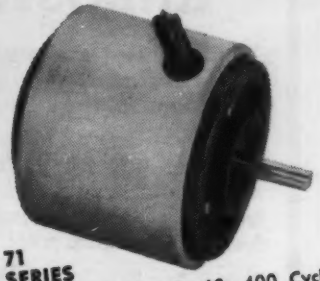
TYPE	H. P.	R.P.M. 60 Cy.
Capacitor	1/15, 1/20, 1/30	1600 & 3200
Shaded Pole	1/30, 1/50, 1/100	1500
Synchronous	1/50, 1/100	1800 & 3600



73 & 74 SERIES

115-200 Volts—50, 60 cycles. Fan or Intermittent duty . . . Sleeve Bearing . . . Totally Enclosed. Outside Diam. 3-5/16".

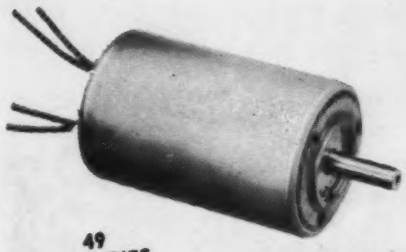
TYPE	H.P.	R.P.M. 60 Cy.
Capacitor	1/20, 1/30, 1/50	1600 & 3200
Shaded Pole	1/30, 1/50, 1/100	1500
Synchronous	1/50, 1/100, 1/200	1800 & 3600



71 SERIES

115-200 Volts—50, 60, 400 Cycles Continuous duty. Sealed Ball Bearings. Totally enclosed. Outside Diam. 3-5/16"—3⅞".

TYPE	H. P.	R.P.M. 60 Cy.
Capacitor	1/15, 1/20, 1/30, 1/50, 1/100	1600 & 3200
Shaded Pole	1/30, 1/50, 1/100	1500
Synchronous	1/50, 1/100, 1/200	1800 & 3600



49 SERIES

115 Volts—50, 60 and 400 Cycles. Continuous duty . . . Ball Bearing. Totally enclosed. Outside Diam. 1¾".

TYPE	H.P.	R.P.M. 60 Cy.
Capacitor	1/100*, 1/250	2800 & 3100
Torque	5 Oz. In.	45*Only

*Intermittent Duty Only

31 SERIES

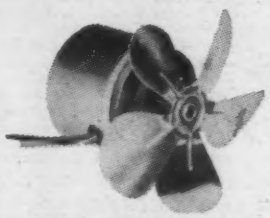
115 Volts, 400 cycles, 1/25 to 1/100 H. P. Weight of units 15 oz. Diam. $1\frac{15}{16}$. Length $2\frac{29}{32}$.

36 SERIES

D.C. Voltage Generators for Control and Tachometer applications . . 2 Volts per hundred R. P. M. Permanent magnet field . . . weight, 20 oz. Diameter 2¼". Length 3".

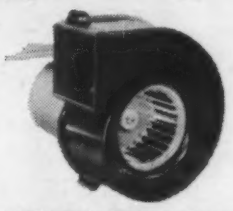
ALTERNATORS

Special Alternators designed for any application. 20 to 1000 cycles up to 50 watts. Specialists in permanent magnet designs.



AXIAL FLOW BLOWERS

Numerous types for 50, 60 and 400 Cycle application. 170 to 800 C.F.M. (NEMA Code). 65 to 300 C.F.M. (NAFM Code). Designed for use in electronic or industrial equipment.



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Numerous Types for 50, 60 and 400 Cycle application. 60 to 110 C.F.M. For use in electronic or industrial equipment.

TYPICAL APPLICATIONS

Cameras and Projectors
Chart Recorders
Floor Fans
Dispensing Machines
Timing Apparatus
Turntables
Air Conditioning

Eastern Air Devices' units embody all of the important advances in design and construction made during the war. Included are such features as: replaceable "capsule" bearings, snap ring construction for easy disassembly, radically improved cooling means, insuring long life with minimum size and weight, etc. Let us fit an E. A. D. unit to your application.

EASTERN AIR DEVICES, INC.

585 Dean Street - Brooklyn 17, N. Y. Tel. Sterling 3-3408
EAD Foreign Dept.-70 Pine St., N.Y.C. Tel Whitehall 4-8729

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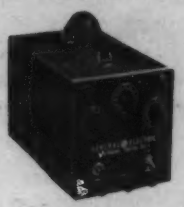
THE GE
ELECTRONIC SWITCH

The General Electric Electronic Switch, Type YE-9, is a device which may be used with a conventional cathode ray oscilloscope for the simultaneous observation of two or more



wave phenomena on the screen of the oscilloscope. Since the cathode ray tube is essentially a single signal indicator, a device such as this is necessary for the observation of more than one signal. Thus, it permits the oscilloscope to be used as a multi-signal comparison device.

The two signals to be observed are applied to the two inputs of the Electronic Switch. The Electronic Switch then performs its function by delivering the individual signals to the output terminal, alternately. Due to the persistence of vision of the human eye, and the persistence of the fluorescent screen, the two signals appear on the oscilloscope screen simultaneously. While the employment of one Electronic Switch permits the simultaneous observation of two waveshapes on the oscilloscope screen, two switches used in tandem may be used to observe three waveshapes, etc.

The instrument requires no adjustment or calibration while in use. It is completely automatic in operation for any range of oscilloscope sweep frequencies from 10 to 12,000 cycles per second. The only controls are the individual Gain Controls for each signal and a Balance Control for separation or superposition of the two signals.

The most frequent uses to which the Electronic Switch may be put are the comparison of amplitude, waveform, phase, and frequency relationships between two signals. The signals under study may be those of an electrical or electronic device, or they may be sound or mechanical motion that are transformed into electrical functions.

TECHNICAL DATA

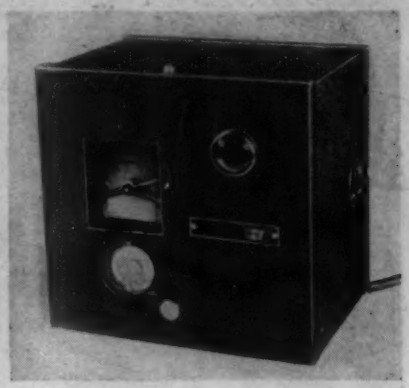
Input voltage	110-125 Volts, 50-60 cycle
Power drain	45 watts
Amplifier frequency response	4 cps to 450 kc (flat within 3 db)
Oscilloscope sweep frequency range	will operate on any sweep frequency of from 10 cps to 12,000 cps, continuously variable
Input impedance	100,000 ohms
Maximum signal input	250 volts rms
Length, overall	12½"
Width, overall	7⅜"
Height, overall	8½"
Weight	14 lbs.

$59.50 Net, F.O.B., New York

Telephone: LOngacre 3-1800

rc HARVEY RADIO COMPANY INC.

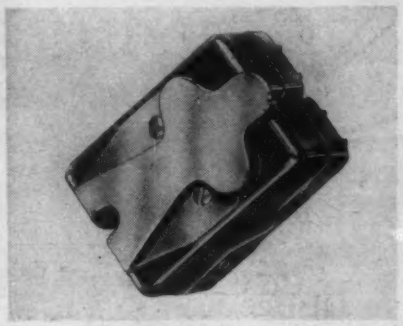
103 West 43rd St., New York 18, N. Y.



ing apparatus on and off at a predetermined time schedule. Operating at 110 volts a-c, the cycle repeats day after day as long as the clock is not disconnected.

Snap Switch (38)

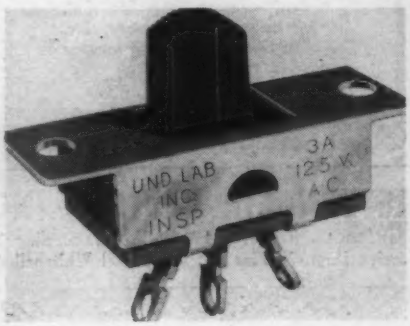
UNIMAX SWITCH CORP., 460 West 34th St., New York 1, N. Y. Type



SA-1 double-pole snap-action switch can be obtained in either double- or single-throw and is made up of two switches joined by an Adaptaplate. The switch is rated at 15 amperes 125 volts.

Snap-Slide Switch (39)

ELPAR CO., Bank & Marlton Ave., Camden, N. J. Type RS Underwriters' approved 3-ampere 125-volt a-c snap action slide switch has a low contact resistance. Max-



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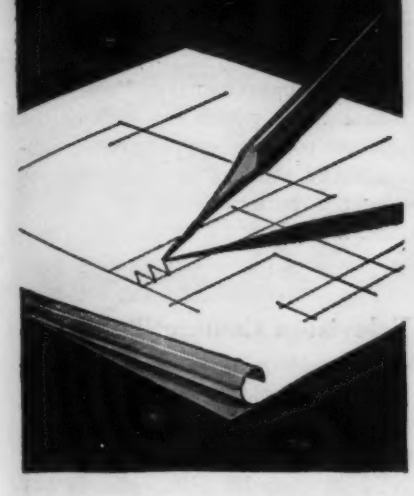

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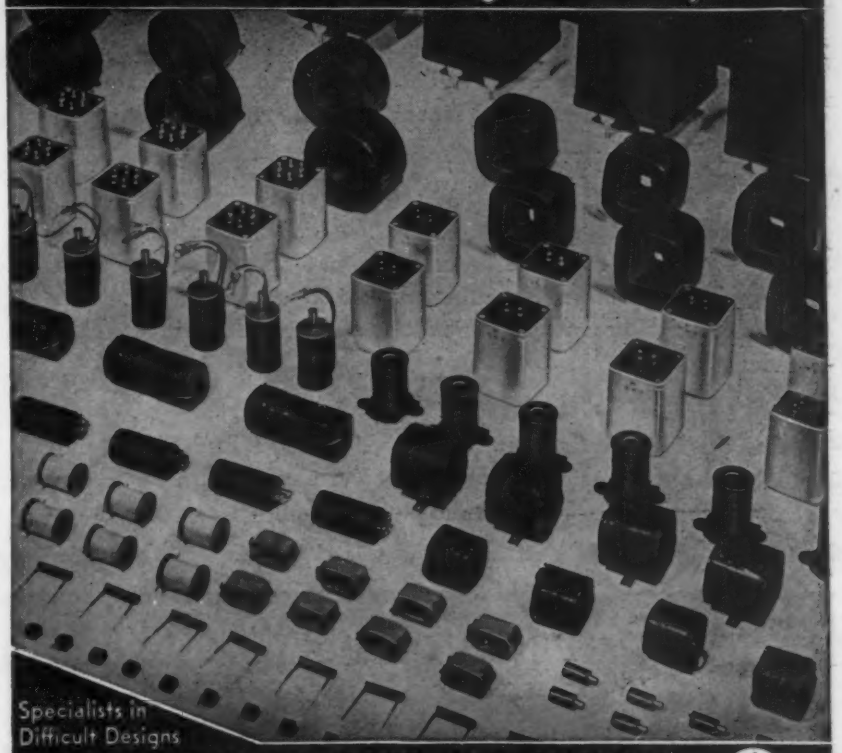

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TYPE RAPC

FOR HIGH SPEED RECORDING and TRANSMITTING

McElroy Manufacturing Corporation announces an entirely new line of high speed recording and transmitting terminal equipment. For the first time, McElroy makes available a mechanical Wheatstone keying head capable of continuous operation at 500 words per minute, and a compact undulator tape recorder which is tested at speeds up to 1500 words per minute, and capable of recording high speed Morse, teletype or other intelligence where a fast accurate pulse mechanism is required.

•

Illustrated are the new ADK and RAPC units. The ADK keys Wheatstone tape at any variable speed up to 500 words per minute and provides polar, voltage, relay, or tone output. The RAPC pulse type recorder will accept contact, tone, voltage and frequency shift input and record such inputs at speeds up to 1500 words per minute.

•

The heart of this equipment is the new McElroy variable speed drive, used in the units described above and in the new high speed tape pullers. Set arbitrarily at 60 words per minute, a Strobotac will reveal no variation in speed with any reasonable load.

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See this new equipment at our booth at the I. R. E. Show, and let our engineers convince you of the new ease in operating possible with the new McElroy equipment.

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imum travel is 0.16 inch, and the switch is selfactuating beyond the center of throw. Two mounting holes are required.

Ferrule Resistor (40)

MILWAUKEE RESISTOR CO., 700 West Virginia St., Milwaukee, Wis. A new ferrule-type line of resistors

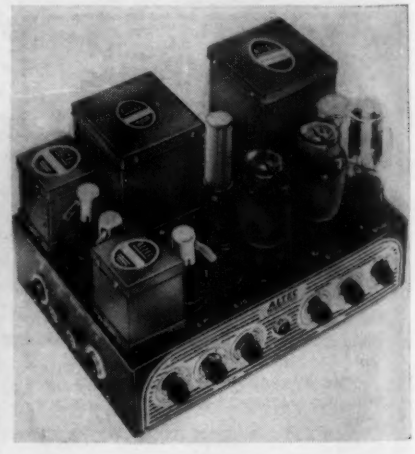
that eliminates separate tips by a technique in which the ends of the resistor core are copper coated substantially reduces production costs over conventional models.
ament.

Television Camera Tube (41)

RADIO CORP. OF AMERICA, Harrison, N. J. The new image orthicon, 5655, is especially recommended for studio use. It differs from the 2P23 in that its photocathode has practically no infrared sensitivity, and it has better resolution, signal-to-noise ratio, and more natural response to halftones.

Portable P-A Amplifier (42)

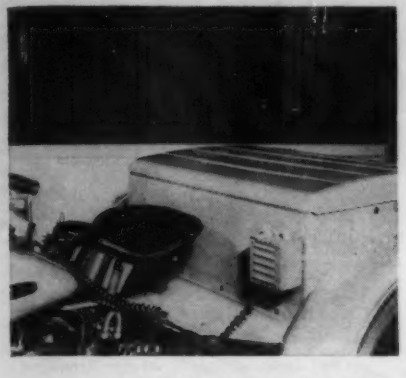
ALTEC LANSING CORP., 250 West 57th St., New York 19, N. Y. A new portable public address amplifier model A-324 is rated at 15 watts with an overall frequency response



flat within 1 db from 20 to 20,000 cycles. Four inputs are provided, two low impedance with 95-db gain and the other two with 72-db gain at high impedance. Variable controls are available for both bass and treble.

Motorcycle Dispatcher (43)

MOTOROLA INC., 4545 W. Augusta, Chicago 51, Ill. Designed for the 152-162 mc band, the new Dis-



patcher unit is a compact mobile radiotelephone transmitter and receiver for motorcycle use with a power output of 7 to 10 watts. The crystal drift is held to less than ± 0.002 percent over a temperature range of − 20 to + 80C.

Mobile Frequency Meter (44)

BROWNING LABORATORIES, INC., Winchester, Mass. Model S-7 frequency meter is particularly useful

for measurements in the 72–76 and 152–162 mc bands. Accuracy of 0.005 percent is easily obtained, and with special precautions in the measurement technique, better than 0.0025 percent is possible. A whip

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by

Northern Radio

A COMPLETE FREQUENCY SHIFT SYSTEM FOR POINT-TO-POINT COMMUNICATIONS

TYPE 107

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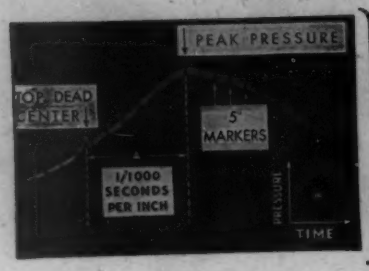

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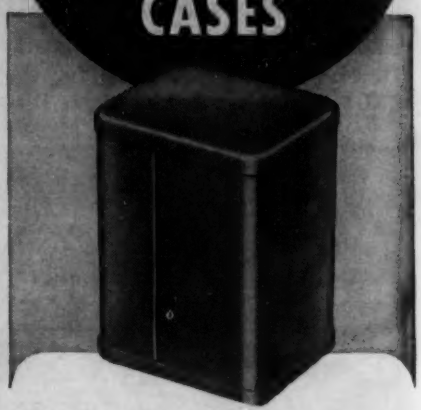

Now available in quantity, OLYMPIC standardized transformer cases are specifically designed to meet all normal requirements where standard cases are used. Construction is rigid, with rounded corners, and tight-fitting covers top and bottom. OLYMPIC standard transformer cases can be furnished with pierced covers, studs, brackets or channels. Inquiries are invited—write for illustrated bulletin—no obligation.

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E1-21	1	1½"	1⅝"	2⁹⁄₁₆"
E1-625	2	1⅝"	1⅞"	2¹¹⁄₁₆"
E1-75	3	2¼"	2⅛"	2¹³⁄₁₆"
E1-11	4	2⅝"	2½"	3¹⁄₃₂"
E1-12	5	3"	2⅞"	3³³⁄₃₂"
E1-3A	6	3¼"	3"	3¹⁵⁄₃₂"
E1-112	7	3⅝"	3¼"	4⁹⁄₃₂"
E1-125	8	3¾"	3½"	4¹⁵⁄₃₂"
E1-137	9	3⅞"	3⅝"	4²³⁄₃₂"
E1-13	10	4⅛"	4¼"	5¹¹⁄₃₂"
E1-151	11	5"	4⅝"	5¹⁵⁄₃₂"
E1-36	12	5⅝"	4¾"	6¹⁵⁄₃₂"

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TOOL & MFG. CO., INC.
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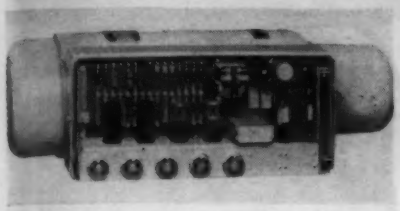
antenna furnishes coupling to the transmitter. Operation is from 117 volts either a-c or d-c.

Electronic Amplidyne (45)

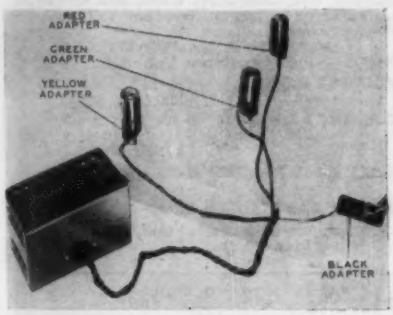
GENERAL ELECTRIC CO., Schenectady 5, N. Y., announces an electronic amplidyne which is useful for precise regulation of current,



voltage speed of motors. The unit consists of a high-gain balanced d-c electronic amplifier and a motor amplidyne. It has an output of 1½ kw, 250 volts and can be used on either a 220- or 440-volt, 3-phase, 60-cycle power supply.

Linearity Check (46)

PHILCO CORP., Philadelphia, Pa. Model 5072 Crosshatch generator enables a television service man



to check and adjust the linearity of a receiver's vertical and horizontal sweeps without depending on test charts from a television station. By means of an adapter harness the unit obtains required plate power, filament power and synchronizing voltages from the receiver itself.

Direct-Coupled Amplifier (47)

AMPLIFIER CORP. OF AMERICA, 398 Broadway, New York, 13, N. Y. Developed to accommodate the G-E

with the GENERAL ELECTRIC VARIABLE RELUCTANCE PICKUP

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Letters from music lovers in increasing numbers tell us how much the General Electric Variable Reluctance Pickup has increased their listening pleasure—how it has brought out new beauty in their old recordings.

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- ★ Only two pin jacks for all standard ranges.

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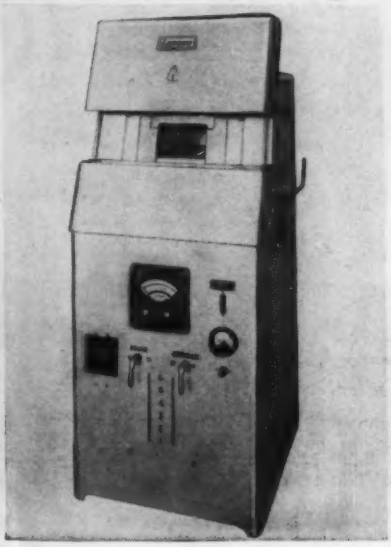
T-V Tubulars (48)

CORNELL-DUBILIER ELECTRIC CORP., South Plainfield, N. J. Type TMC-

187 capacitor developed for television service has a capacitance of 0.005 microfarads at 3,500 working volts, d-c.

Laboratory Furnace (49)

LINDBERG ENGINEERING CO., 2444 West Hubbard St., Chicago 12, Ill. has developed the model G-10 box type electronically controlled laboratory furnace with temperatures up



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TUNED-RIBBON Pick-up model SA-79
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Jewel Stylus EASILY REPLACED BY USER

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SPECIFICATIONS TUNED-RIBBON SA-79

- Linear 50 cyc. to over 10 k.c.
- Point Pressure—about 24 grams
- Genuine Sapphire Stylus—EASILY REPLACED BY USER
- Output—about—30 db
- Impedance—200 ohms to 500 ohms
- Vibratory Momentum—very low
- Quick plug-in connectors
- Arm is aluminum, Special Studio Design, Tangent-Tracking, ball-thrust and pivot-point bearings in gimbal mounting—eliminating side thrust and drag.

TUNED-RIBBON delivers not only Wide Range, (which is but one line in the chain)—but also the vital factors so necessary for quality performance and EAR-acceptability . . . proving anew AUDAX right to the slogan:—

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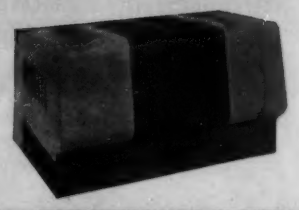

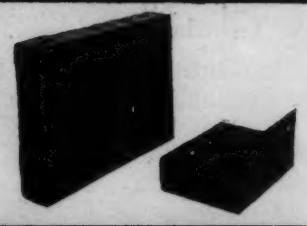

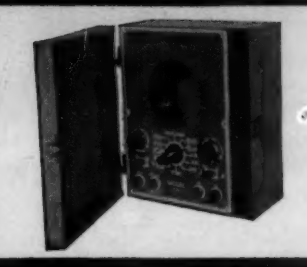

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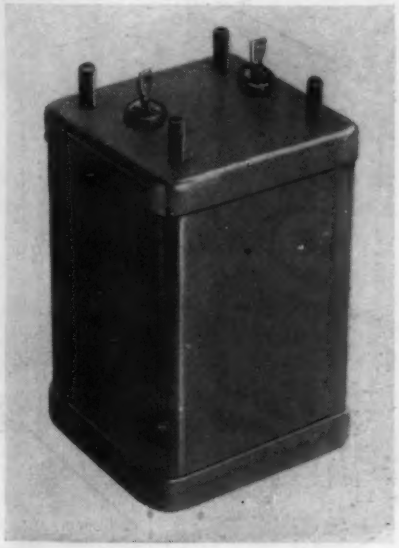
Signal Calibrator (50)

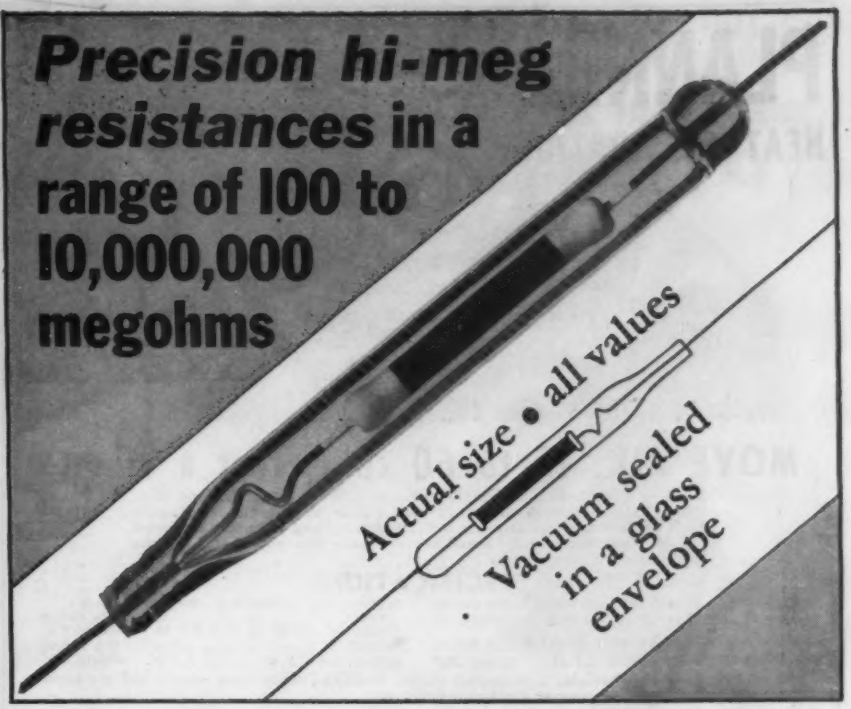
INDUSTRIAL ELECTRONICS, INC., 21 Henry St., Detroit 1, Michigan. The Electro-cal is an instrument pro-

viding precision measured signal voltage for calibration purposes. Output signals in the form of 60-cycle sine waves up to 1,000 millivolts are available in eight ranges. An output signal of 0-5 volts can also be read directly on the meter.

Plastic Capacitors (51)

UNITED CONDENSER CORP., 422 E. 138th St., New York 54, N. Y. Plastic dielectric capacitors with su-




Precision hi-meg resistances in a range of 100 to 10,000,000 megohms
Actual size • all values
Vacuum sealed in a glass envelope

Victoreen HI-MEG resistors were developed for use in electrometer circuits and other applications were stability, accuracy, and high humidity operation are of prime consideration. The resistor element is vacuum sealed in a glass envelope. A special silicon varnished surface makes the hi-meg less susceptible to humidity effects than other circuit components. A carefully controlled accelerated aging process insures stability and reliability. The range of 100 to 10,000,000 megohms assures full coverage in values which were hitherto unobtainable. Production is current.

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Radiation instrumentation

Victoreen "know how" of radiation measuring instruments is based on a background of 20 years devoted exclusively to such problems and assures quality performance for your particular needs.

These include laboratory and survey instruments to measure alpha, beta and gamma radiation, for personnel protection, field surveys and such fine components as the VX series subminiature electrometer vacuum tubes and the VG series Geiger counter tubes.

These components and instruments such as the 356 Alpha meter, the 263A beta and gamma meter, the 247A gamma radiation survey meter, and the 287 minometer and pocket ionization chambers have contributed to the history and are pacing the progress of radiation instrumentation.

Write for information and data sheets.

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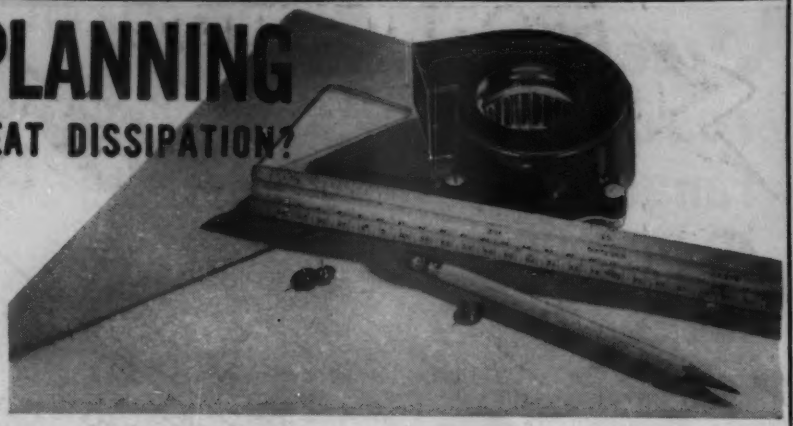

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There is a light, compact, highly efficient L-R Blower giving you maximum heat dispersion under all climatic or temperature conditions. Each of these blowers requires minimum space and produces maximum C.F.M. Specifications are listed below so that you may choose the size best suited to your needs.

SPECIFICATIONS

MODEL 1½, Weight (without motor)...2½ ounces
Output: 15 C.F.M. at 8000 R.P.M. Height 3"

MODEL 2, Weight (without motor).....5 ounces
Output: 25 C.F.M. at 8000 R.P.M. Height 3¾"

MODEL 2¾, (illustrated) Weight (without motor).....5½ ounces
Output: 50 C.F.M. at 8000 R.P.M. Height 4½"

MODEL 3, Weight (without motor)...12½ ounces
Output: 200 C.F.M. at 8000 R.P.M. Height 6½"

All models have light-weight, high-impact plastic housings, turbo type wheels and are made with either clockwise or counter clockwise rotation.

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SO. AMERICAN REP. Jose Luis Pontet Cordoba 1472 Buenos Aires, Argentina

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Luxtron photocells convert light directly into electrical energy. No external source of voltage is required. Besides the housed model shown with its plug-in contacts, Bradley also offers tube socket, nut-and-bolt types and pigtail contact mountings. In addition, Luxtron unmounted cells are available in many different sizes and shapes.

*T. M. REG. U. S. PAT. OFF.

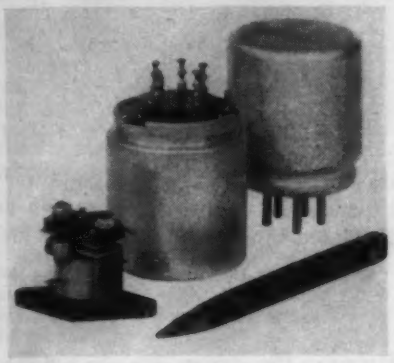
Illustrated literature, available on request, shows more models of Bradley photocells, plus a line of copper oxide and selenium rectifiers. Write for "The Bradley Line."

BRADLEY LABORATORIES, INC.
82 Meadow St. New Haven 10, Conn.

perior electrical characteristics are available in a wide range of voltage and capacitance. They can be furnished to close tolerances with housings either hermetically-sealed metal, glass or ceramic, or wax-sealed cardboard tubes.

Current-Sensitive D-C Relays (52)

GENERAL ELECTRIC CO., Schenectady, N. Y. Eight types of single-pole, double-throw, current-sensi-



tive, d-c relays are announced. Input ratings range from 10 to 180 milliwatts, 0.47 to 1,470 milliamps, and 0.07 to 67,000 ohms. Additional information is given in GEA-3819D.

Air Variables (53)

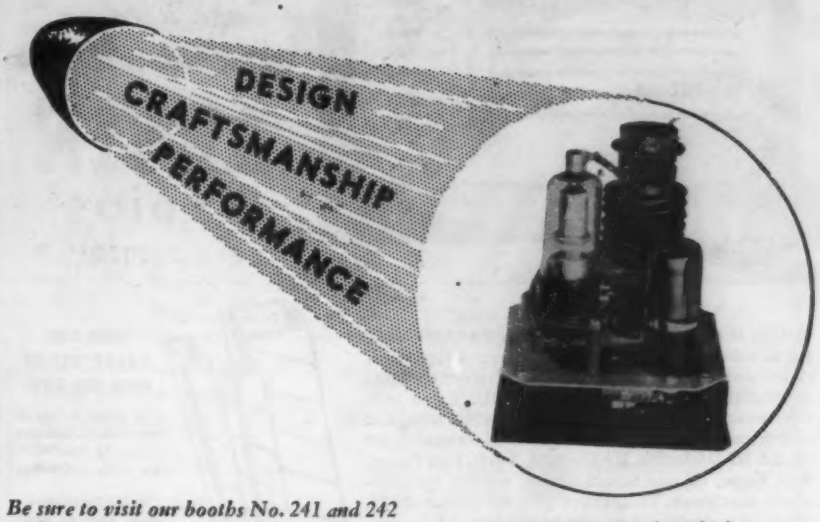
E. F. JOHNSON CO., Waseca, Minn. A new line of air variable capacitors is available in single, differen-

tial, and butterfly types. Each of the three is available in four different capacitances. All have single-hole mounting, steatite end frames, and beryllium copper contact springs. Full details are available from the manufacturer.

Power Triode (54)

RADIO CORP. OF AMERICA, Harrison, N. J. The 5671 is a forced-air-

SPOTLIGHTING Super TELEVISION HI-VOLTAGE POWER SUPPLY



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2. Model A supplies up to 7000 volts D.C. at 800 micro-amperes. Power input required: 300 volts D.C. at 50 milliamperes and 6.3 volts at .45 amperes.
3. Model B supplies up to 10,000 volts D.C. at 1 milliampere. Power input required: 360 volts D.C. at 90 milliamperes and 6.3 volts at .9 amperes.
4. These units are of the r.f. type and eliminate the hazards inherent in other types of high voltage power supply.

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	535–1620 kc	1.6–5.6 mc	5.6–19.25 mc	535–1620 kc	2.0–6.0 mc	6.0–18.0 mc	88–112 mc	TELEVISION
OSCILLATOR COIL	•	•	•	•	•	•	•	•
LOOP ANTENNA	•			•				
ANTENNA COIL	•	•	•	•	•	•		•
R-F INTERSTAGE TRANSFORMER	•	•	•	•	•	•	•	
BAND PASS ANTENNA COIL (Double Tuned)	•			•				
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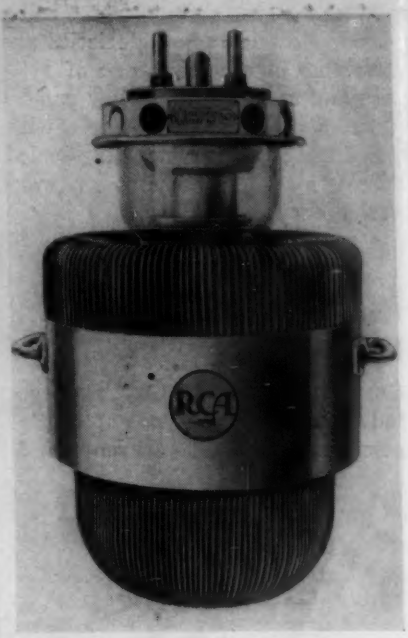
Descriptive Bulletin No. 10 Available

BALLANTINE LABORATORIES, INC. BOONTON, NEW JERSEY, U. S. A.



cooled power triode for high-power broadcast stations. It contains a thoriated-tungsten, multistrand filament.

Burner Program (55)

COMBUSTION CONTROL CORP., 77 Broadway, Cambridge 42, Mass. Fireye program control type 24PJ8

provides automatic starting and programming for commercial oil burning equipment. Full details of the equipment are given in Bulletin CD4751.

Mercury Contact Relay (56)

POTTER & BRUMFIELD MFG. CO., 549 West Washington Blvd., Chicago 6, Ill. has developed a mercury contact relay especially for current control in installations where there is danger due to ignition of fumes, dust or gas by arcs from open switches. The unit is sealed and

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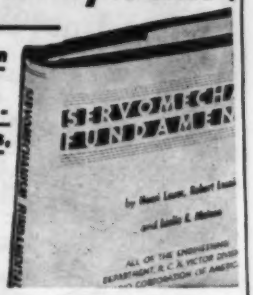

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All of the Engineering Department, RCA Victor Division, Radio Corporation of America

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5. Analysis of Servomechanisms with Error-rate Damping
6. Analysis of Servomechanisms with Combined Viscous Output Damping and Error-rate Damping
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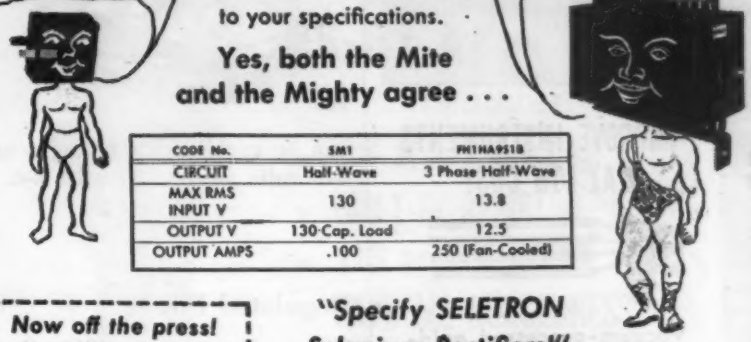

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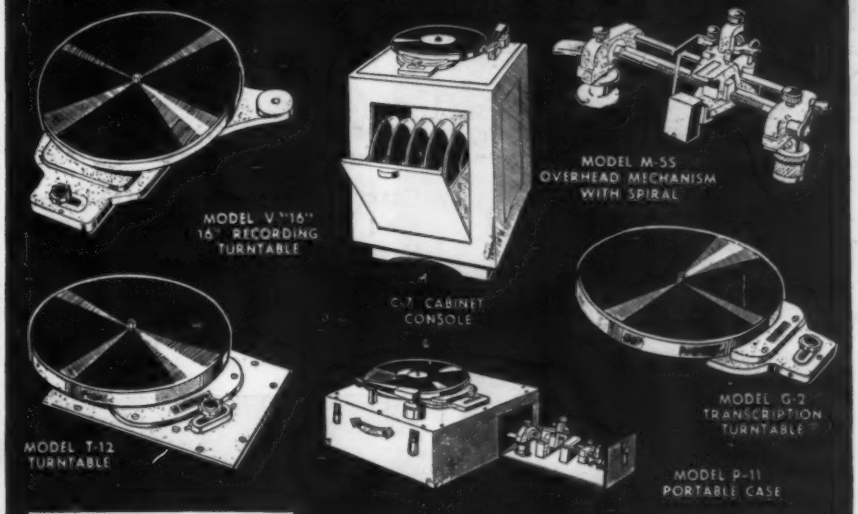
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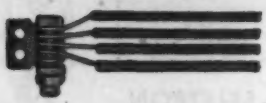
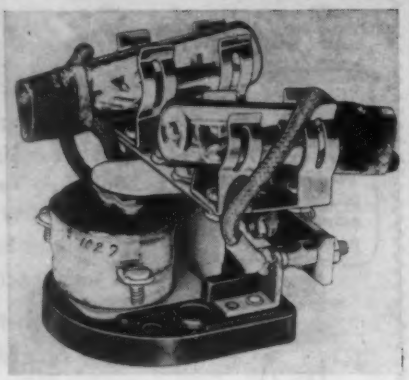


Vacuum-processed, gold-coated Bradley instrument rectifiers increase equipment efficiency. Especially designed for use where stability and permanence of calibration are important, "Coprox" rectifiers meet the most exacting requirements. Yet they cost no more than ordinary rectifiers — in most cases, less.

Temperature error is exceptionally low with Bradley rectifiers. Aging is practically nil. Pre-soldered leads. Rating of CX-2E series up to 4.5 volts A.C., 3 volts and 5 milliamperes D.C.

Illustrated literature, available on request, shows more models of copper oxide rectifiers, plus a line of selenium rectifiers and photocells. Write for "The Bradley Line."

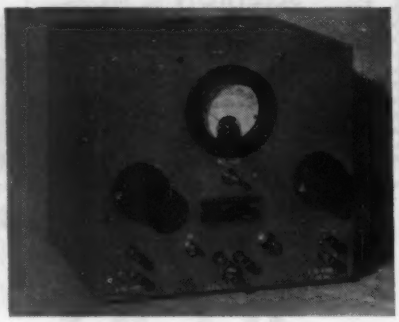
BRADLEY LABORATORIES, INC.
82 Meadow St. New Haven 10, Conn.



can be supplied for voltages up to 440 volts a-c or 230 volts d-c.

Regulated Power (57)

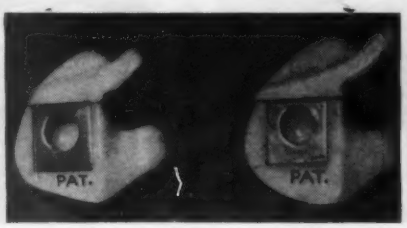
RADAR ENGINEERS, 1319 Second Ave., Seattle 1, Wash. Type RPS-3 regulated power supply furnishes



up to 300 volts at 50 milliamperes; down to minus 105 volts bias; and 6.3 volts at 2 amperes for heaters. Regulation is within 1 percent over most of the range. A voltmeter reads either positive or negative outputs.

Variable Earpiece (58)

CRYSTO-PLASTICS LAB., 110 East 42nd St., New York, N. Y. The Universal-Variable earpiece comes in only two sizes, but can be adjusted to fit any ear. Any miniature receiver unit can be attached



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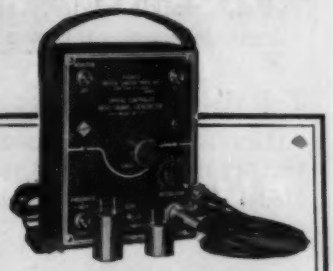

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Extreme versatility is combined with laboratory precision in the new Premier Model 117 Crystal-Controlled Mini-Signal Generator.

The ultimate in accuracy is provided by the new Premier Model 117 Mini-Signal Generator. Its micrometer adjustment enables the user to zero-beat the crystal with standard frequency transmissions of WWV, and affords the utmost in precision in setting up frequency markers throughout the entire radio spectrum.

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for AMATEUR operations
in SERVICE WORK
for general FIELD use . . .

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Packed With Facts **— This four-page technical bulletin is full of detailed engineering data and specifications on the new Premier Mini-Signal Generator: circuit diagrams, construction details, operating instructions, exclusive features that make it more valuable and versatile for myriad uses. Write for Bulletin 117.**

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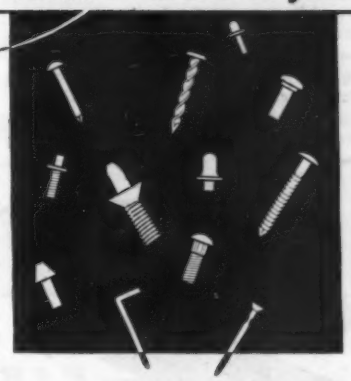

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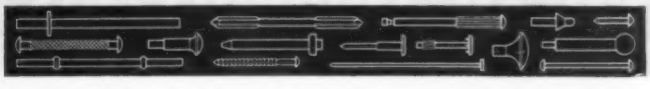

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Model V

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This unit is designed for use as an oscilloscope deflection amplifier for the measurement and viewing of pulses of extremely short duration and rise time, and contains the Video Amplifier Unit, Power Unit and a Low Capacity Probe.

Specifications:

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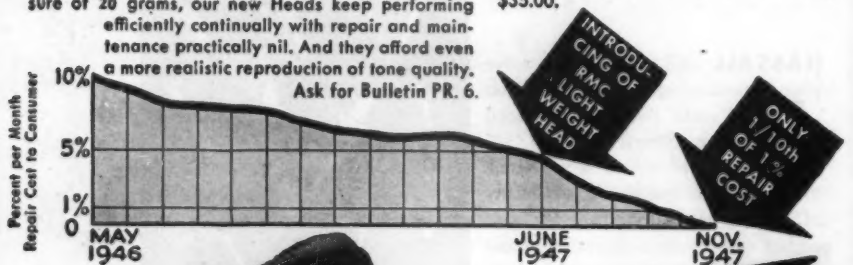

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for use with hearing aids, pocket radios, walkie-talkies, or other communications equipment.

Television Film Pickup (59)

ALLEN B. DUMONT LABORATORIES, INC., 42 Harding Ave., Clifton, N. J. Model TA-512-A dual iconoscope

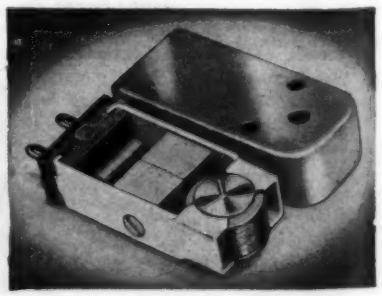
film pickup for which the control console is illustrated has been designed for the use of either positive or negative film on television programs. Electronic fading circuits are provided. The projection equipment is housed in wall cabinets.

Television Recorder (60)

EASTMAN KODAK CO., Rochester 4, N. Y. A 16-mm motion picture camera has been developed for use in television studios for recording movies directly from the face of a monitoring picture tube. Pictures are taken at the rate of 24 frames a second. The device can be used for reprogramming or for record purposes.

Variable Reluctance Pickup (61)

CLARKSTAN CORP., 11927 West Pico Blvd., Los Angeles 34, Calif. The Clarkstan RV pickup has exact velocity response to 15,000 cycles. Needle force of 20 grams is optimum for commercial pressings. As customarily furnished, the pickup has a high impedance but it can be obtained in impedances of 5, 50,



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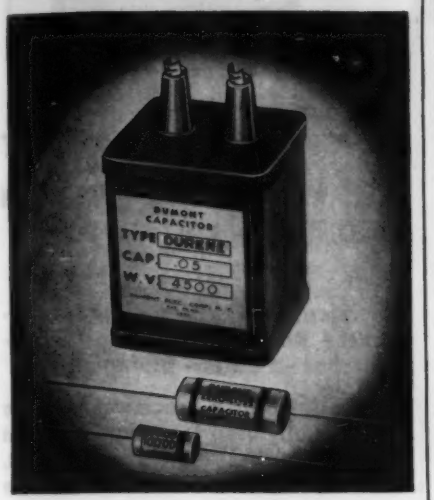

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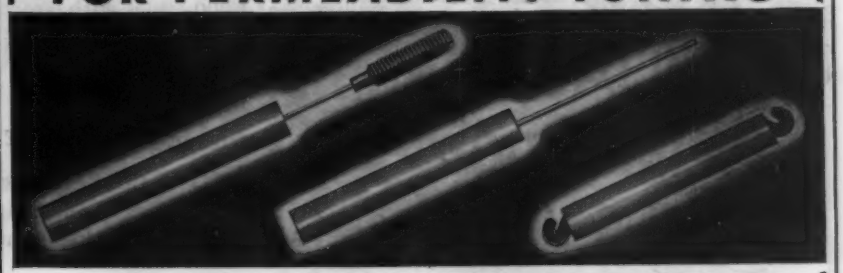

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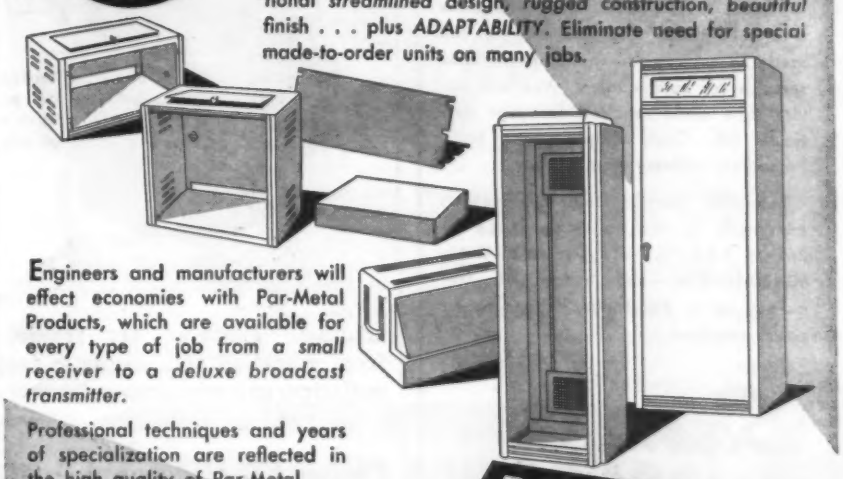

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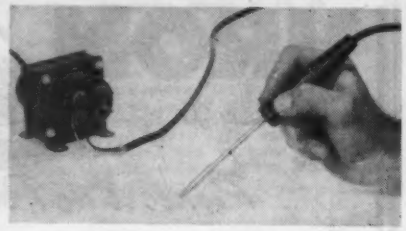
250, and 500 ohms. Output is 60 millivolts at 1,000 cycles with lateral displacement of 0.001 inch.

Midget Soldering Iron (62)

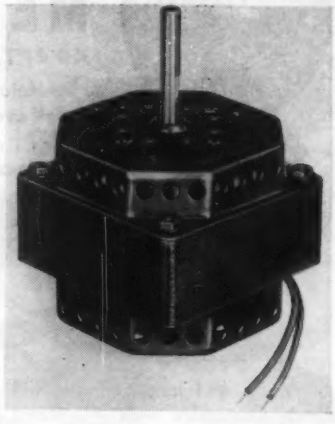
GENERAL ELECTRIC Co., Schenectady, N. Y. A new midget soldering iron is 8 inches long, has tips ¼ and



⅛ inch in diameter and weighs 1¾ ounce without the cord. It operates from 6 volts, consuming 25 watts and is illustrated with the step-down transformer used to adapt it to normal socket voltage.

Smooth Power Motor (63)

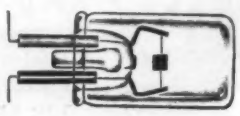
GENERAL INDUSTRIES Co., Elyria, Ohio. An improved model RM-4 small motor for use in wire and tape recorders has recently been an-



nounced. Features are freedom from vibration and magnetic field radiation, and minimum noise.

Vacuum Thermocouple (64)

FIELD ELECTRICAL INSTRUMENT Co., 109 East 184th St., New York 53,



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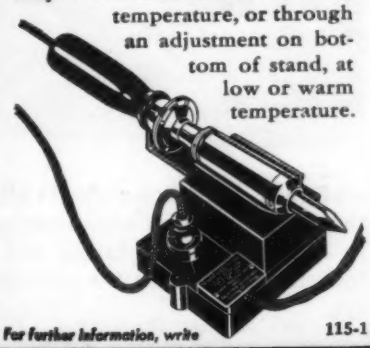

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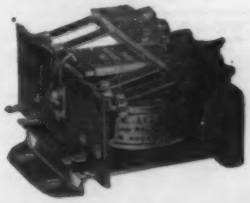

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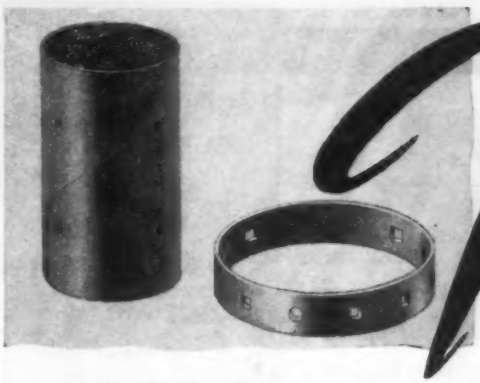

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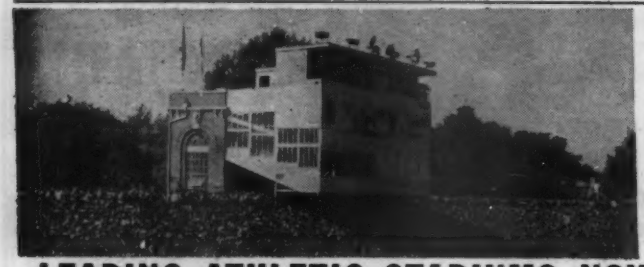

University of Michigan stadium, Ann Arbor, Mich. Altec Lansing large multicell horns driven by Altec Lansing ½ KW amplifier, are centralized over press stand, override noise level of 86,000 spectators. Reiss Public Address Systems, Detroit, contractors.

LEADING ATHLETIC STADIUMS NOW CHOOSE ALTEC LANSING PUBLIC ADDRESS SYSTEMS

With million dollar "gates", sports are big business today; leading stadiums throughout the United States, both college and professional, able to afford the best, are installing Altec Lansing public address systems, or are converting previous unsatisfactory systems to Altec Lansing. Altec Lansing produces systems with sufficient power to override high crowd noises with complete intelligibility; high efficiency, directional-character multicell speakers are clustered at one place, thus simplifying installation. Other stadiums using Altec Lansing systems: Griffith, Washington, D. C.; Gardens Arena, Pittsburgh; University of Utah; Briggs, Detroit; etc.

Authorized Altec Lansing stadium specialists will submit estimates and plans on your own stadium public address requirements. Address: Stadium Engineering Department F, 1161 N. Vine St., Hollywood 38, or 250 West 57th St., New York 19.

Above: large multicell Altec Lansing speakers. Below: Altec Lansing 287W ½ KW industrial amplifier.

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Wire Division
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N. Y. The type R radiation vacuum thermocouple now available generates about 356 microvolts from the heat of a lamp consuming 546 watts at a distance of 1 meter. Details are given in Bulletin V24.

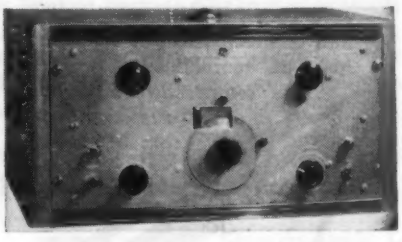
Public Address Mike (65)

AMPERITE CO., INC., 561 Broadway, New York 12, N. Y. The new velocity microphone model RBHG (high impedance) and RBLG (50 to 200 ohms) has a frequency response

from 50 to 11,000 cycles within plus or minus 2 db. Output is minus 62 db. The ribbon itself has a peak at 10 cycles.

Capacitance Meter (66)

GENERAL ELECTRIC CO., Syracuse, N. Y. Type YCL-1 r-f capacitometer measures capacitance at 75 kc directly from 0 to 1,000 micromi-



crofarads. Calibration charts allow the measurement of capacitance up to 20,000 micromicrofarads and of inductance up to 10,000 microhenrys.

Liquid Level Indicator (67)

ENGINEERING LABORATORIES, INC., 610 East Fourth St., Tulsa 3, Oklahoma. The Gagetron is a device

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Wire Recorder (68)

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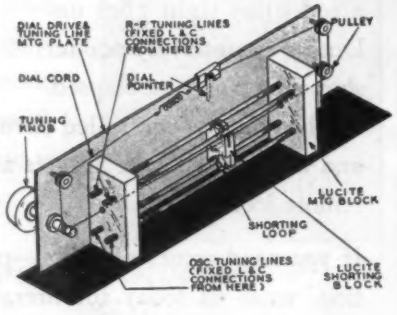
F-M Tuner (69)

EDWARDS FM RADIO CORP., 168 Washington St., New York 6, N. Y. The Fidelotuner comprising two tunable lines and a movable shorting block is now available for experimenters who desire to build f-m tuners.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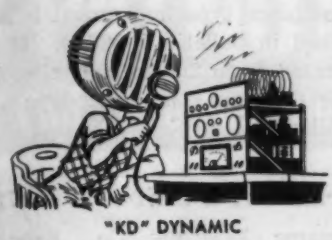

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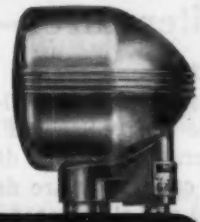

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Within 10 Millivolts at any voltage or load with ratings.

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ENGINEERING "KNOW-HOW"
Type TG
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oscillator type D-105-A has a frequency range from 1 cycle to over 100 kilocycles. This resistance-capacitance type instrument is described in bulletin B-528-D. It is operated from 200 to 250 volts, 50 cycle through a magnetic-type a-c stabilizer.

Variable A-C Unit (71)

SUPERIOR ELECTRIC Co., Bristol, Conn. The new Voltbox is a portable source of a-c voltage and comprises a variable autotransformer mounted on a special aluminum base equipped with outlets and switches as well as a meter.

Literature

(72)
Capacitors. Cornell-Dubilier Electric Corp., South Plainfield, N. J. More than twenty different classes of capacitors are described in detail and illustrated in the new 24-page catalog No. 200. The handy reference book also includes list and net prices.

(73)
Technical Bulletins. Radio Corp. of America. Single page technical bulletins are available on each of four new additions to the tube line. The new tubes are the 6AV6, 12AV6, 5618, and 5652.

(74)
Magnetic Phonograph Pickups. Lear, Inc., 11916 West Pico Blvd., Los Angeles 34, Calif. The design of new magnetic recorder heads which may be used for stainless steel wire recordings is described in a 4-page reprint. Schematics and response curves are included.

(75)
Transformers. Raytheon Mfg. Co., Waltham 54, Mass. General design data is listed in a four-page brochure on transformers, reactors, and saturable magnetic components.

(76)
Wire Recording Heads. Lear, Inc., 11916 West Pico Blvd., Los Angeles 34, Cal. Two sheets give ample

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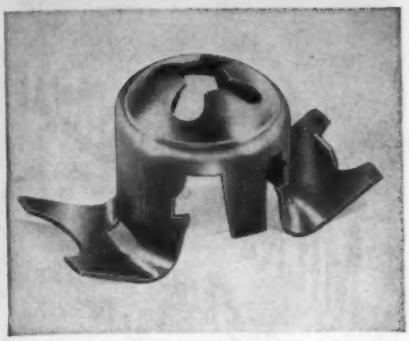
Trademark

Coil Tube Fasteners



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coverage of performance data and installation specifications for the magnetic wire recording head WH-200 and reproducing WH-201.

(77)

Commercial Crystals. Bliley Electric Co., Erie, Pa. Bulletin 36 is a well-illustrated, complete listing of all except amateur types of quartz crystals for all types of commercial applications.

(78)

Remote Shaft Rotation. Ford Instrument Co., Inc., 31-10 Thomson Ave., Long Island City 1, N. Y. Telesyn and other motors are described in 16 catalog pages. Bulk of the information concerns apparatus for remote control of shaft rotations.

(79)

Fixed Radiophone. Belmont Radio Corp., 5921 West Dickens Ave., Chicago 39, Ill. Model US 20-1 fixed station radio equipment is a compact 20-watt unit for use in conjunction with a mobile radiophone. Its specifications are listed in a four-page booklet.

(80)

Constant Voltage Transformers. Sola Electric Co., 2525 Clybourn Ave., Chicago 14, Ill. Bulletin CV-102 gives construction and operating theory, as well as a wide variety of data and a complete catalog of standard constant voltage transformers.

(81)

Radioassays. Tracerlab, Inc., 55 Oliver St., Boston 10, Mass. In volume No. 7 of Tracerlog are found a complete description of radioassay procedures. Three pages are devoted to the SC-9A manual sample changer with preamplifier, designed to standardize radioactivity analyses.

F-M Servicing. General Electric Co., Syracuse, N. Y. A handy 28-page booklet (ESD-21) on f-m servicing, well-illustrated with schematics, block diagrams, sketches and curves, is available from distributors for twenty-five cents.

Silicone News

DC SILICONES

DC Silicones Help Maintain High Performance Standards of Portable SoundScriber

DC 33 Silicone Grease permanently lubricates portable SoundScriber gear drive. DC 4 Compound damps vibrations in playback head.

A portable recording machine that can be used in your car is obviously subject to operation in extremes of temperature. Yet turntable speeds are critical. The SoundScriber Corporation, New Haven, Connecticut, has solved this problem with a sealed gear drive mechanism permanently lubricated with DC 33 Silicone Grease.

Here are the benefits reported from the use of DC 33 Silicone Grease in the drive mechanism:

1. It eliminates the need for relubrication; DC 33 does not evaporate or dry out.
2. DC 33 retains its consistency and provides effective lubrication at temperatures ranging from —95° to 300° F. It therefore permits the motor to start easily and operate satisfactorily when cold; it does not thin out and leak through bearing joints at high temperatures as do other greases or oils having a low enough torque at low temperatures.

And here are the advantages of DC 4 Silicone Compound as used in the playback heads of all models of the SoundScriber:

1. It effectively damps the moving coil of this playback uniformly at any temperature—giving an "oil damping" effect without requiring elaborate sealing devices.
2. DC 4 is inert to most organic materials. It can, therefore, be used in direct contact with the rubber supports in the playback heads.

Dow Corning Silicone Products are notably indifferent to temperature changes. They possess other unique properties that may be even more useful to you. We've had nearly five years' experience in the commercial production of Silicone Greases, Fluids, Resins, and Silastic*. Telephone the branch office nearest you for engineering assistance, or write for Catalog N1-3.

*TRADEMARK FOR DOW CORNING SILICONE RUBBER

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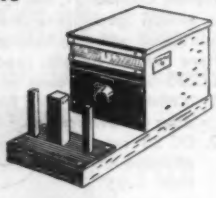
PRECISION POTENTIOMETERS

Twenty-seven laboratory and portable models for precise voltage measurement. Widely used as laboratory standards in meter calibration and for thermocouple measurements. Bulletin 270.

COIL TESTERS

For rapid low-cost production testing of shorts and opens in coil windings of nearly every shape and size. Bulletin 109.



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STANDARD RESISTORS

Reichsanstalt and National Bureau of Standards types from 0.001 ohm up to 10,000 ohms, limit of error 0.02% and 0.01%. Standard shunts from 0.00002 ohm to one ohm, limit of error 0.04%. Bulletin 100.

SPECIAL INSTRUMENTS

In addition to the partial listing of instruments above, the Rubicon Company produces a wide variety of special equipment involving in one way or another the precise measurement or control of some electrical quantity. Inquiries for equipment to meet special needs are invited.

RUBICON COMPANY

Electrical Instrument Makers

3757 Ridge Avenue • Philadelphia 32, Pa.

(continued from p 148)

may be obtained from the U. S. Naval Observatory, Washington 25, D. C.

The Canadian Dominion Observatory (Ottawa) broadcasts time signals continuously over station CHU on frequencies of 3,330, 7,335 and 14,670 kc; and at certain hours over other stations located at Ottawa, Halifax, and Churchill. Information may be obtained by writing the Dominion Observatory, Ottawa, Canada.

A comprehensive list of United States and foreign radio time signals is given in chapter 3 of "Radio Navigational Aids", Hydrographic Office publication No. 205, for sale by the Hydrographic Office, Washington 25, D. C., price $1.25.

IRE Convention Space Increased

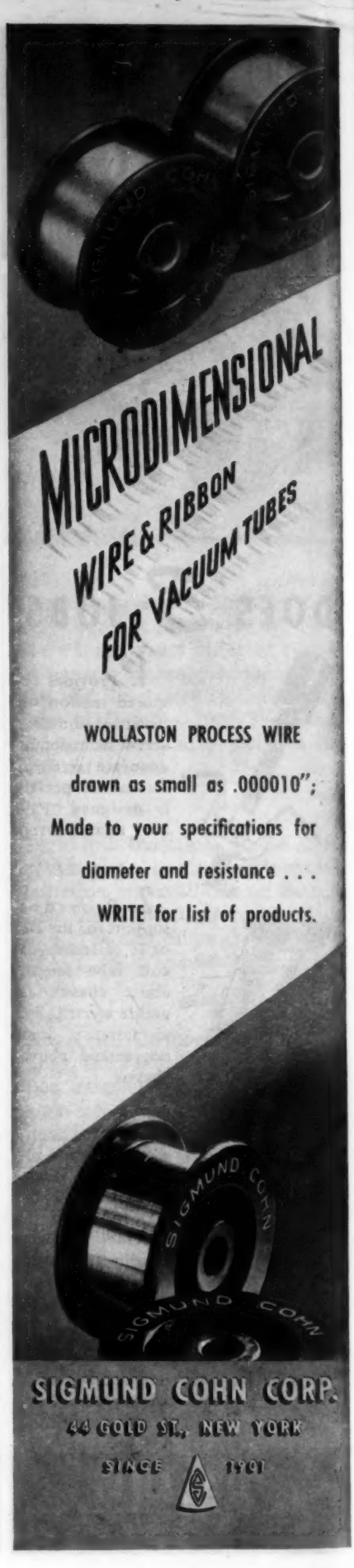
HALF of the third floor of Grand Central Palace in New York City will be used for exhibits at the IRE 1948 Engineering Show, March 22-25, in addition to the first two floors. Radio-electronic Frontiers, the theme of the 1948 Show, will focus attention on the new progress and markets of the industry. The technical program this year consists of 130 papers in 26 sessions, plus two special symposia.

Electronic Warfare Training

FORMATION of an extensive electronics warfare program for the Reserves has been planned by the U. S. Marine Corps. The program will stress training in the fields of gca for aircraft, pilotless aircraft, radar, and television. Units will be concentrated geographically in areas where the electronic industry flourishes. Candidates will be chosen on the basis of their technical background, professional skill, and willingness to enroll in study courses in their chosen fields.

Plans are made for 560 units (each composed of an officer and nine enlisted men): 10 special tactical; 250 radar, missile, and pilotless aircraft; 200 radio and communication; 100 telephone communication.

A nationwide Marine Corps Reserve Radio Network will be set



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SEE— 175 exhibits of radio components, parts, instruments, sound systems and transmitters.

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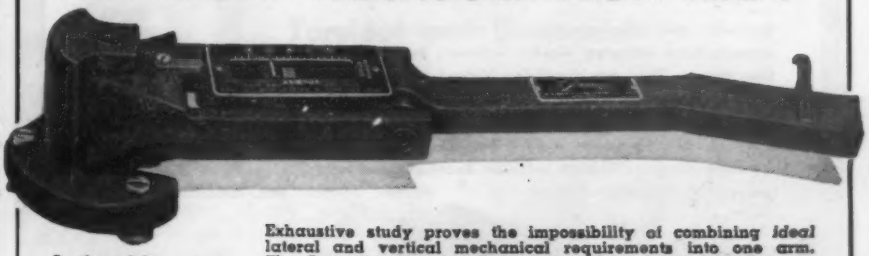


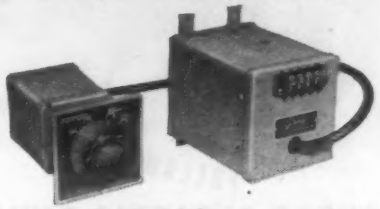
Featherweight magnesium, frictionless motion, adjustable stylus pressure, self-leveling base.

Exhaustive study proves the impossibility of combining *ideal* lateral and vertical mechanical requirements into one arm. The Gray Transcription Arm, designed for finest lateral reproduction accommodates all modern cartridges—General Electric, Pickering, etc.—has been adopted as standard equipment by national radio networks including CBS, ABC and numerous independent radio stations. Arm less cartridge $35.00.

DIAMOND G.E. CARTRIDGES!

At last a permanent solution to the quality pick-up problem. We can now supply a Selected G.E. Cartridge with finest quality Diamond Stylus for mounting in the Gray Transcription Arm. The practically unlimited life of the Diamond Stylus makes it an exceptionally economical investment at $29.63 net to radio stations.

Gray Equalizer For G.E. Cartridge



FOR RADIO STATION USE. No. 601, 4-position Equalizer (Flat, N.A.B., etc., etc.) expertly engineered for use with the G.E. Variable Reluctance Cartridge. Matches pick-up to microphone channel. Adopted by radio networks. Complete $42.50.

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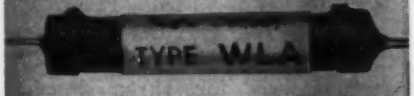

WL—1" x 3/16" (Radial Lead) .01 Ohms min.
WLA—1" x 3/16" (Axial Lead) 10,000 max.

New Economy Line!

Here's a new line of resistors priced for real economy. Wire wound to a tolerance of 1% — higher accuracy on special order at slightly higher cost. Write today.

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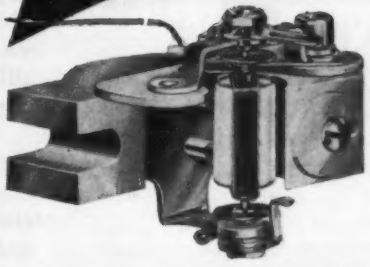

MAGNETS OF ALNICO are standard for all DC instruments because it is the most stable magnetic material available, having greatest resistance to effects of stray magnetic fields, vibration, shock and heat. All ranges AC and DC available in 2½", 3½", 4½", rectangular or round case styles and are fully guaranteed for one year against defects in workmanship or material. Refer inquiries to Dept. F-38.

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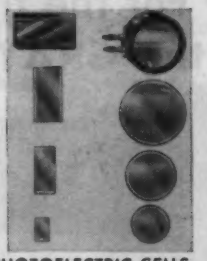
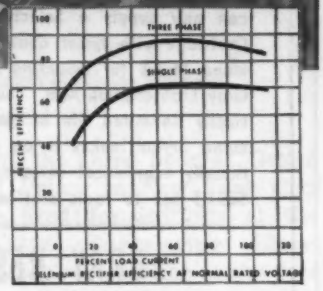
Engineers and Designers who insist on dependable components have adapted Vickers Selenium Rectifiers into their circuits. They are specifying Vickers products, and are submitting their rectifier problems to us. Our greatly expanded plant facilities, plus the recognized dependability of Vickers products, make it possible for us to offer the most complete line of Selenium Rectifiers and self-generating Photoelectric Cells.



PHOTOELECTRIC CELLS



3-1

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MODULATION: 400 cycle internal audio oscillator. Deviation directly calibrated: 0 to 30 kc. and 0 to 300 kc. Can be modulated from external audio source.

Audio fidelity is flat within 2 db from dc to 15,000 cycles. Distortion less than 1% at 75 kc. deviation.

The Model 78FM when used with Measurements Model M-27.5 Converter provides output in the IF ranges of 4.5, 10.7 and 21.7 mc.

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up to function in conjunction with the Naval Reserve Communication net.

Reservists will receive instruction in all phases of electronics through correspondence courses, lectures, training films and recordings. Units will be provided with the latest equipment necessary for thoroughly training personnel in operation, maintenance, and tactical application. Training will also include field trips to both civilian and military electronic laboratories, manufacturing plants, radio communication facilities, and telephone companies.

Individuals interested in participation in this program may obtain complete information from the nearest Marine Corps Reserve activity, or by writing to the Electronic Warfare Section, Division of Reserve, Headquarters, U. S. Marine Corps, Washington 25, D. C.

Research Corporation Awards

AS THE RESULT of a National Research Council survey of the undergraduate origins of those receiving a Ph.D. in physics over a 10-year period, two men were given special awards by Research Corp. (holder of Cottrell electrical precipitation patents and other donated patents). A. A. Knowlton, professor of physics at Reed College, Portland, Oregon, received a special award for his record of stimulation and inspiration of undergraduates for three decades. Clifford N. Wall, who left North Central College at Naperville, Illinois in 1944 for a permanent physics staff appointment at the University of Minnesota, was likewise specially awarded with a plaque and honorarium of $1,000.

Lee DuBridge, now president of the California Institute of Technology, was voted an annual award in recognition of his scientific contributions in the field of radar and his outstanding administration of the wartime microwave laboratory. The other annual award was presented to Merle A. Tuve of the Carnegie Institution of Washington, for scientific contributions in

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Premax Telescoping Tubular Antennas are widely used for reception and transmission by amateurs, and for commercial, mobile and emergency installations. They may be had in sectional types, in steel, aluminum or monel —with extended heights of 5 to 35 feet. Due to their carefully engineered construction, they get the signal.

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For use in computing and analyzing devices; generation of low frequency saw tooth and sine waves; controls for radio and radar equipment; position indicators; servomechanisms; electro medical instruments, measuring devices—telemetering; gun fire control where 360° rotation, high precision and low noise levels are essential.

The type RL14MS sinusoidal potentiometer is illustrated. It is wound to a total resistance of 35,400 ohms and provides two voltages proportional to the sine and cosine of the shaft angle. It will generate a sine wave true within ±.6%. Overall dimensions are 4⅜" diameter x 4 11/32 long plus shaft extension ¼" diameter x 1¼" long.

Write for Bulletin F-68

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FOR
ELECTRIC WIRES

Condenser Plates
Small Metal Stampings
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Modern Equipment and Factory
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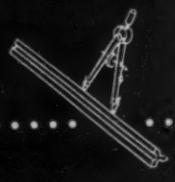

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MOTOR GENERATOR SETS
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KLIPSCH SPEAKER SYSTEM

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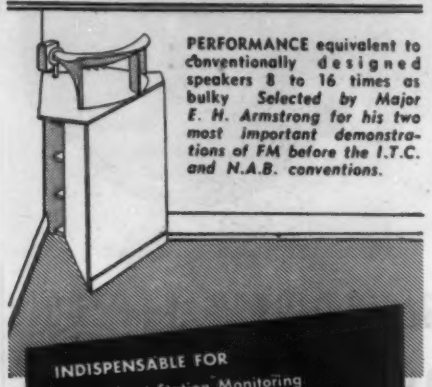
30 to 15,000 cycles



PERFORMANCE equivalent to conventionally designed speakers 8 to 16 times as bulky *Selected by Major E. H. Armstrong for his two most important demonstrations of FM before the I.T.C. and N.A.B. conventions.*

INDISPENSABLE FOR
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The KLIPSCH Speaker System design utilizes the corner of a room as an integral part of the acoustic system, the walls and floor being in effect an extension of the low frequency horn

- ***FUNDAMENTAL TONES*** down to 30 cycles per second.
- ***CLEAN RESPONSE*** throughout the range of hearing
- ***LOW DISTORTION*** and intermodulation at all frequencies.
- ***PERFECT DISPERSION*** of middle and high frequencies throughout the entire room.
- ***HIGH EFFICIENCY:*** Because of the horn loading, acoustic output for a given input power is several times that of conventional speakers.
- ***NON-RESONANT: BASS TONES ARE REPRODUCED*** — not generated by the speaker. Instruments of low pitch are clearly recognized; one hears the original tone — not one created by the loudspeaker.

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making possible the proximity fuze and outstanding administration of the groups which equipped the armed forces with this device.

Navy Aids to Research

UNDER its electronics program during the fiscal year 1947 the Office of Naval Research helped the following laboratories to convert to peacetime basic research: Cruft Laboratory at Harvard, using the Radio Research Laboratory; Reseach Laboratory of Electronics at MIT, using facilities of the Radiation Laboratory; Insulation Research Laboratory at MIT, to initiate research on insulation material with special emphasis on dielectrics.

Research under ONR contracts has been started on direction finding, nonlinear devices with special attention to magnetic amplifiers, and observation of electromagnetic radiation in the radio frequency spectrum from the Milky Way, the sun, and other celestial bodies.

New research tools have come into use for studying superconductivity and ferromagnetism at microwave frequencies. Ultrasonic power can now be generated at frequencies as high as 1,000 mc, with possible applications to moving target indicator problems and storage requirements in digital computers. Microwave techniques have proven useful in the construction of linear accelerators for nuclear research.

The Naval Research Laboratory reported production of a c-r tube for storing signals indefinitely, a simulator tube, a new type of microwave oscillator, and a sealed model of a high-power magnetron. It also engaged in much research in communications in general, radio techniques, search radar countermeasures, and systems utilization.

The NRL Radio Division originated, and demonstrated for the first time during the past year, two basically new radar tracking systems. Also developed were two subminiature ten-channel pulse-time airborne telemetering systems, and multichannel communication equipment for the 225-400 mc range.

In the field of sound, investiga-

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GE Electronic-tube SOCKETS

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GOOD purchasing calls for G-E sockets along with General Electric tubes. That way you have one convenient source of supply—one manufacturer responsibility—one high standard of quality.

Also . . . these heavy-duty sockets are designed to work in harness with G-E power tubes, rectifier types, thyratrons, and others. Depend on General Electric sockets to accent efficient, dependable tube performance; to underscore long service life.

Stocked widely, G-E sockets are easy to obtain. Your nearest G-E electronics office gladly will give you prices and full information. Or write *Electronics Department, General Electric Company, Schenectady 5, N. Y.*

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DEPENDABILITY
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Whatever your requirements in iron-powder parts, Lenkurt can supply Trancors with outstanding operating characteristics. A complete line of low-cost standard cores and assemblies with and without inserts. For special needs—including complete filter assemblies—a competent staff of engineers is at your disposal. Write for catalog.

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SAN CARLOS, CALIF.

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that carry power around any corner have many new uses in peace-time developments. Faithful, dependable power drives or remote control in airplanes, automobiles, radio, and many other commercial products.

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PRECISION

CRYSTALS

RH-9

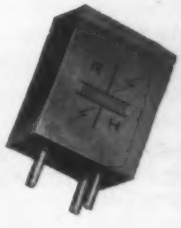
RH-7B

Reeves-Hoffman Crystal Units are produced under rigidly controlled manufacturing conditions. Low humidity, close temperature control, and dust free air assure precision and dependable performance of each unit.

RH-12

Individual Testing of each unit assures uniformity of production. All units of a type must produce the same test results.

Pre-Aging of All Crystal Units and etching to frequency assures not only extreme accuracy but prevents any future frequency drift due to aging.



RH-53

For Complete Information write for catalog RHC-1.

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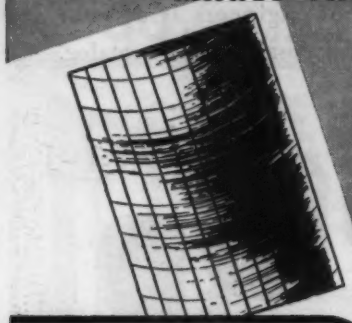
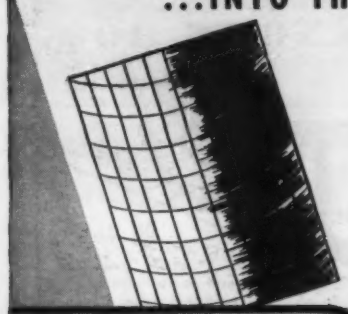
MAKES THIS



Average program level before Limiter action

. . . INTO THIS



Representing between 80% and 100% average modulation after PROGAR action.

These simultaneous records of actual network program prove that PROGAR's dual action . . . fast acting peak limiting preceded by automatic gain control . . . can maintain a higher percentage of modulation for your station.

Note how PROGAR's automatic gain control action moves up decreases in average program material within limiting range. This means less critical monitoring and a louder signal in your listeners' homes.

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tion led to the development of new types of crystals and a special technique for growing quartz crystals.

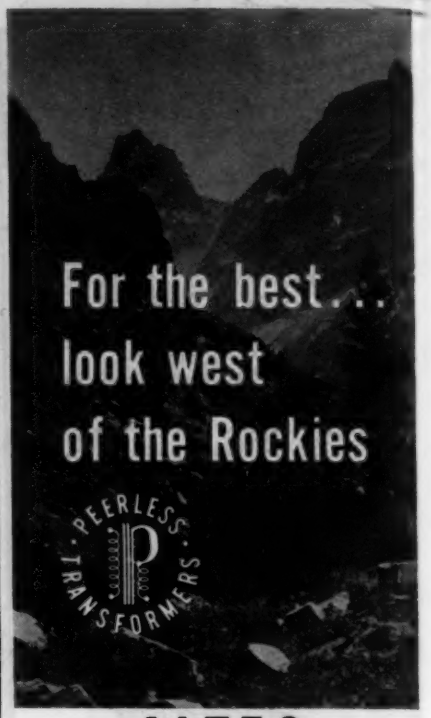
SAE Report on Automotive Radio Installations

THE SOCIETY OF AUTOMOTIVE ENGINEERS has published a 45-page report dealing with applications of two-way radio communication to the operation of automotive fleets. A subcommittee of the society, composed of truck fleet operators and 23 engineers from the communications and automotive industries and headed by W. C. Baylis, communications engineer of the New York Power and Light Corp., collaborated in the preparation of the report.

Subjects studied and reported on include selection of automotive generators and batteries to accommodate the increased load due to the radio equipment; physical description of radio equipment and the space requirements for its installation; antenna space and mounting requirements; selective calling systems; safety features to be included in the design and installation of equipment; licensing of operating personnel. Charts and sample calculations to aid in determining generator and battery requirements are incorporated in the report along with tables of weights and dimensions of typical two-way radio equipments.

Range of Reliable Communication

General conclusions were reached by the subcommittee as to the range of reliable communication that can be had in the three frequency bands available for mobile communication. In the 30–44-mc band, with 250 watts of transmitter power at the fixed station, ranges of 10 to 15 miles can be obtained. In open country, with favorable conditions, this range will increase to 40 to 50 miles. The 152-162 mc band will provide ranges of 8 to 10 miles in cities and 25 to 35 miles in open country. This high-frequency band appears to be less influenced by obstructions in urban areas than does the 30–44-mc band. The more recently available frequency band of 72–76-mc was given only limited tests, but appears to have a range comparable to that of the 30-44-mc



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From 20 cycles to 20,000 cycles

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band and noise level typical of the 152–162-mc band.

Cost of the 30–44-mc equipment was about $500 at the time the report was prepared, while that of the 152–162-mc gear was $600. The cost of 72–76-mc equipment is between these two figures. These estimates do not include the cost of selective calling equipment, installation expenses, nor the cost of changes to existing automotive electrical equipment that may be necessary in making a radio installation.

Copies of the report may be had from the Society of Automotive Engineers, Inc., 29 West 39th St., New York, N. Y. Price is $2.00 to nonmembers of the SAE and $1.00 to members.

BUSINESS NEWS

TELEX, INC., Minneapolis, Minn., has added to its hearing aid laboratory an annex 10,000 sq ft in area and two stories high, to house the tool and die and precision plastic divisions.

New annex of Telex, Inc.

MICROWAVE EQUIPMENT CO. recently opened a new showroom and general offices at 397 Bloomfield Ave., Verona, N. J. Manufacturing facilities are being expanded to include test components for the microwave frequencies.

THE NATIONAL ASSOCIATION OF RELAY MANUFACTURERS held its first annual meeting on January 16 and 17, in Chicago. A complete report of its progress in standardization of specifications and nomenclature for electrical relays was given.

WIRE RECORDING CORP. OF AMERICA has taken over the assets and manufacturing facilities of St. George Recording Equipment Co. of New York City. The new plant is at 1331 Halsey St., Brooklyn, N. Y.

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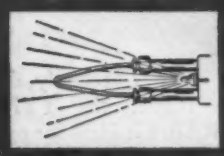
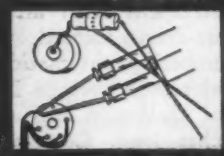

BUILT-IN SPOTLIGHT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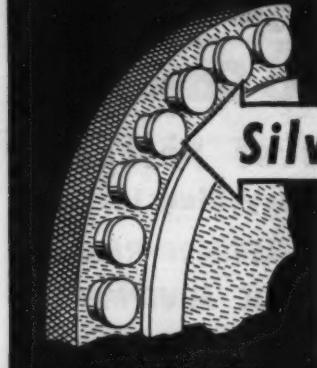

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with new contacts

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Manufacturers of Precision Electrical Resistance Instruments

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and Measures, in January 1948. The new unit is about 0.05 percent smaller than the International Ohm formerly used; resistors having 0.1 percent accuracy or better will therefore be made to the new standard, identified by abs stamped on the label.

SYLVANIA ELECTRIC PRODUCTS, INC., has begun construction of Sylvania Center, a campus-type electronic research development at Bayside, N. Y. The research project, under the direction of Bennett S. Ellefson, is designed for the long-term peacetime development of electronic and lighting equipment, television, f-m, and radar.

UNITED ELECTRIC CONTROLS CO., Boston, Mass., manufacturers of electric temperature, pressure, and vacuum controls, moved to larger quarters in Watertown, Mass.

RADIO CORP. OF AMERICA has announced a million-dollar expansion program providing an additional 40,000 sq ft of floor space for television tube production at its Lancaster, Pa., plant.

ACHESON COLLOIDS CORP., Port Huron, Michigan, now occupies its new plant with increased manufacturing and laboratory facilities, supplemented by those of its newly purchased London subsidiary, E. G. Acheson, Ltd.

New Acheson Colloids plant

OHMEGA LABORATORIES, INC., Pine Brook, N. J., recently formed outgrowth of Kay Electric Co., will carry out special development work for the parent company and manufacture instruments for electronic measurements.

PERSONNEL

WAYNE COY, radio director of the Washington Post, was appointed chairman of the FCC by President Truman, with confirmation of his nomination by the U. S. Senate to fill out the term of former chair-

New SUPERHET TUNER

by "Adaptol" *has*

numerous valuable applications for MANUFACTURERS.

Efficient and Economical

"Adaptol" Superhet Tuner is *compact.* Highly suitable for use in conjunction with Wire and Tape Recorders. Has many *Experimental* uses . . . *Tuner* for Custom-Built Radios . . . Has many *"conversion"* uses.

CIRCUIT FEATURES: *Self-contained power supply* for 110V D.C. A.C. 50-60 cycles . . . *Three tube circuit* of conventional design, using the *latest miniature and dual purpose tubes.* Oscillator-converter; I.F.-2nd detector; A.C. rectifier . . . Permeability tuned drift-free I.F.'s . . . Approx .5 volt audio output across interval .5 megohm internal load resistor, on average B.C. signal with five foot antenna . . . Units individually tracked at FOUR points through tuning range of 540-1700 kc . . . **COMPACT:** Approximately 4½"x3½"x3-¾".

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Our production for over one year has been confined to small quantities which could be carefully field checked for performance while working in the equipment of which they were a component.

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It is with a feeling of accomplishment that we state our reject rate has never exceeded 3%—this only on a very special application which involved high sensitivity accompanying a very low resistance requirement.

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The accuracy of our statements may be checked with our customers. At your request we will forward names of those in your territory who are purchasing these instruments and profiting by their low cost.

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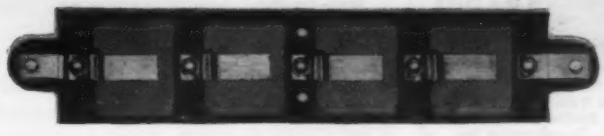
Announcing The STRIP-TYPE HALF-WAVE

SELENIUM RECTIFIER

—A *New* ARCTURUS *Development!*



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- REPLACES THERMIONIC RECTIFIERS in many radio and electronic circuits. Consists of 4 series-connected rectifying elements in a fibre base to form a wafer-thin planar strip.
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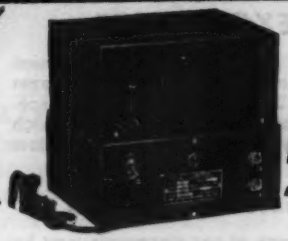

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man Charles R. Denny. He previously served as director of NAB and of FM Broadcasters, Inc., predecessor of the present FM Association.

W. Coy

G. E. Sterling

GEORGE E. STERLING, formerly chief engineer of the FCC, was named by President Truman to succeed E. K. Jett (resigned) as a member of the FCC. He has been associated with radio since 1913 when he took out the first amateur license in the state of Maine. His recent appointment became effective with Senate approval.

R. L. SMITH-ROSE, new IRE vice-president, was promoted to director of radio research in the Department of Scientific and Industrial Research, London. He had been superintendent of the radio division of the National Physical Laboratory since 1939 and was responsible for extensive investigations in radio direction finding and propagation of radio waves over the ground and through the lower atmosphere.

JOHN A. WILLOUGHBY has been designated acting chief engineer of the Federal Communications Commission.

CARLTON WASMANSDORFF, for six years superintendent of communications for the Glendale, Calif. police department, is now in charge of development engineering for Hoffman Radio Corp., Los Angeles. He was at one time chief engineer for Maguire Industries in New York, and served two years in San Francisco as chief engineer for Globe Wireless.

NEAL MCNAUGHTEN, former chief of the allocation section of the FCC engineering department's broadcast division, recently became assistant director of the engineering depart-

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Connections are made through Fanning Strip, on bench or anywhere apart from barrier strip, and quickly slipped into assembly.

9-141 Barrier Strip

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Use with Jones Barrier Terminal Strips, Nos. 141 and 142, for 1 to 20 terminals.

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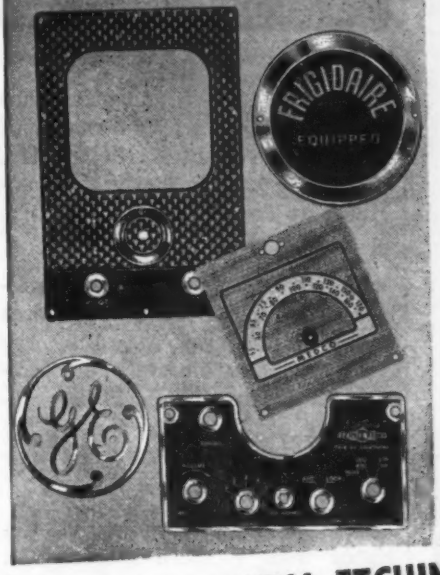

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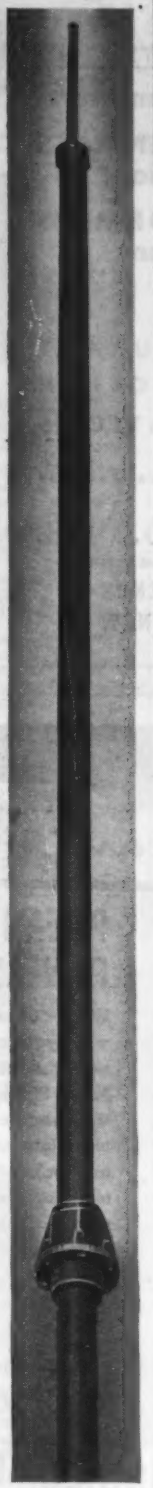
Permit the use of low power, low cost equipment.

Workshop High-Gain Beacon Antennas are designed specifically for the 152-162 megacycle band —taxicab, fire, police, and private fleet communications.



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ment of the National Association of Broadcasters.

FRANK G. BACK received the Television Broadcasters Association award for the development of the Zoomar Lens, which makes possible instantaneous following of action by the camera.

JAMES A. MCGREGOR, formerly an engineer with the American District Telegraph Co. and associated with MIT Radiation Laboratory from 1940 to 1945, is now president of Microwave Equipment Co., Verona, N. J.

NEWELL A. ATWOOD, Commander, USN, engaged in electronics duty with the Navy since 1941, is now Electronics Officer at the New York Naval Shipyard, Brooklyn, N. Y.

VIRGIL M. GRAHAM, director of technical relations for Sylvania Electric Products, Inc., Flushing, N. Y., has been elected chairman of the Joint Electron Tube Engineering Council sponsored by RMA and NEMA.

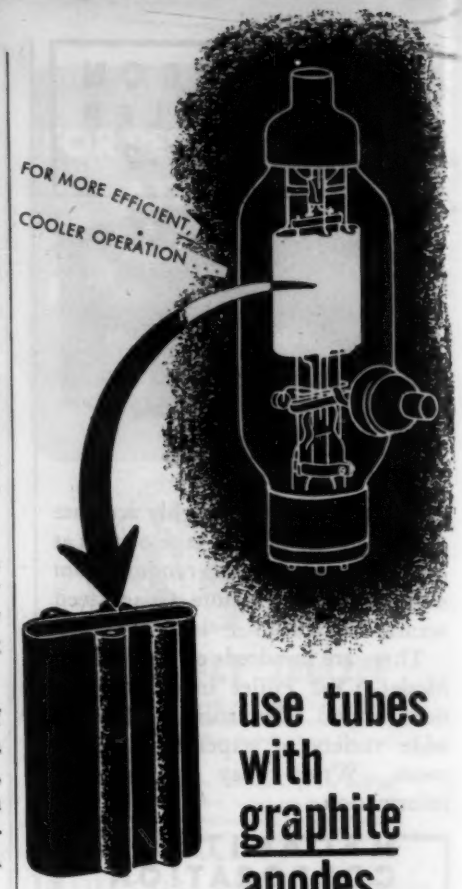
V. M. Graham

E. D. A. Geoghegan

EAMONN D. A. GEOGHEGAN has been appointed factory manager of the Chicago plant of Solar Mfg. Corp. He was formerly chief engineer at Tobe Deutschmann Corp. in Canton, Mass.

WILLIAM C. EDDY, director of television at WBKB in Chicago, was presented with an award by the Television Broadcasters Association for application of existing microwave equipment to a relay between South Bend, Ind., and Chicago.

EDWIN T. KAISER, previously associated with Western Electric Co. as design engineer and with Essex Electronics Co. as plant manager, has been appointed production manager of U. S. Fiber & Plastics Corp., Stirling, N. J.



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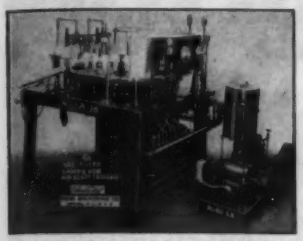

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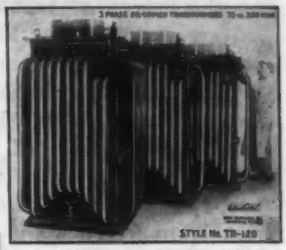

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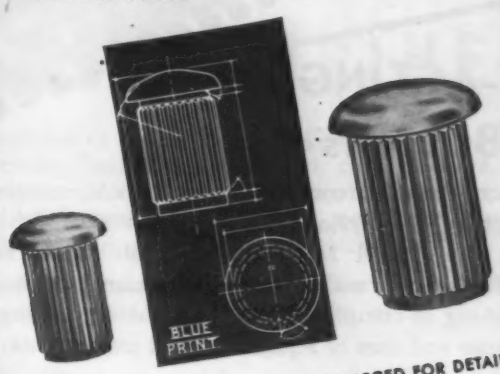

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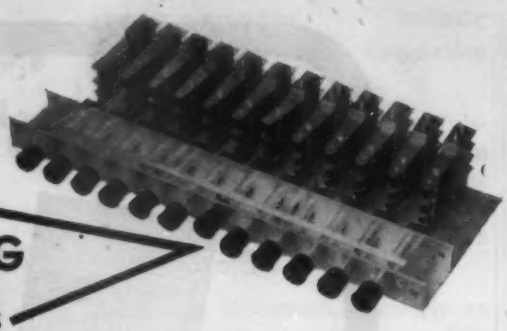

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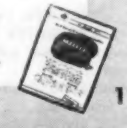

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BY THE STAFF OF THE RADIO RESEARCH LABORATORY, *Harvard University. McGraw-Hill Book Company, Inc., New York, N. Y.*, 1947, 1,057 *pages*, $14.00 *per set of two volumes.*

THESE VOLUMES are concerned primarily with the problems incident on the design of transmitters, receivers, transmission lines, and antennas of considerable bandwidth in the frequency region from 100 to approximately 10,000 mc. The greater proportion of the discussion is confined to the region from perhaps 300 mc, where conventional lumped-constant circuits become impractical, to about 6,000 mc, which marks roughly the upper limit of the more successful designs. Of course, the discussion of designs at higher frequencies may have been limited by security considerations. In addition to the unusual bandwidth requirements, the discussion differs from other presentations of wartime radar research in the emphasis on c-w rather than pulse techniques.

There is a great deal of interesting material contained in these volumes. The presentation suffers somewhat from the difficulties which inevitably accompany multiple authorship; the differences in terminology and points of view of approximately 50 authors have not been completely eliminated. Thus, in one chapter on antennas, gain otherwise unspecified means gain relative to an omnidirectional radiator, while in another the same term denotes gain relative to a dipole.

A fairly successful attempt to eliminate repetition in various chapters where fields of interest overlap has been made by extensive cross-referencing. However, this has the rather unfortunate result that many of the figures illustrating one chapter are likely to be found in another and, indeed, frequently in the other volume.

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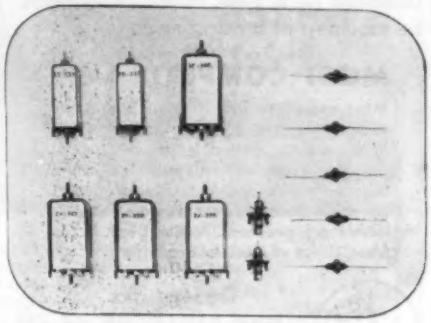

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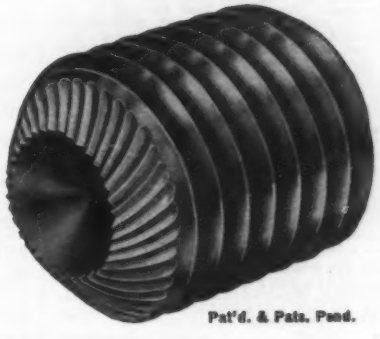

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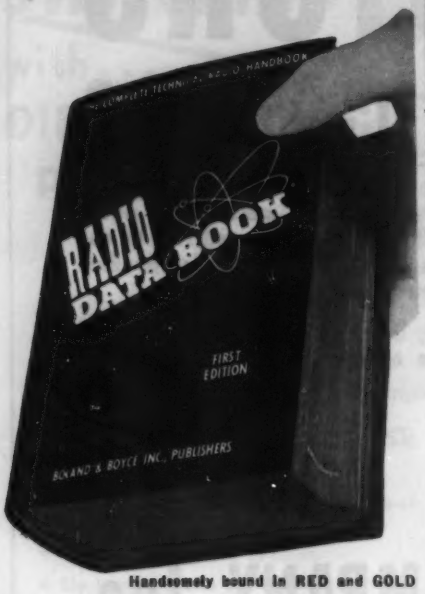

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An adequate index is included, together with a bibliography; the latter is probably most valuable for its inclusion of a list of recently declassified internal reports available through the Department of Commerce.—B. J. MILLER, *Chief, Guided Missile Electronics Section, Ordnance Development Division, National Bureau of Standards.*

Frequenz Modulation

BY PAUL GUTTINGER. Verlag AG *Gebr. Leemann & Co., Zurich* 39, *Switzerland*, 1947, 183 *pages*, *Fr.* 25.

THIS compact, authoritative, essentially mathematical volume on phase and frequency modulation furnishes an excellent theoretical foundation to teachers, students at graduate level, and research and design engineers who are interested in f-m and can read technical German.

Three relatively independent chapters cover General Theory of Frequency and Phase Modulation, Distortion, and the Influence of Interference in F-M. In the chapter on distortion, criteria for distortionless transmission are established and formulas developed which permit calculation of distortion in single-and double-tuned circuits. Formulas are also developed for distortion due to multipath transmission which lead the author to the conclusion that transoceanic f-m transmissions are not feasible. The discussion on interference includes an analysis of imperfect limiting which is particularly timely in view of the appearance on the market of a number of so-called f-m receivers that could profit immeasurably by the application of the principles covered in this section.

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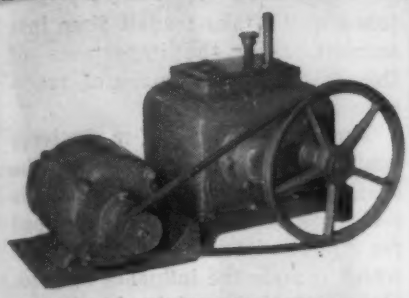

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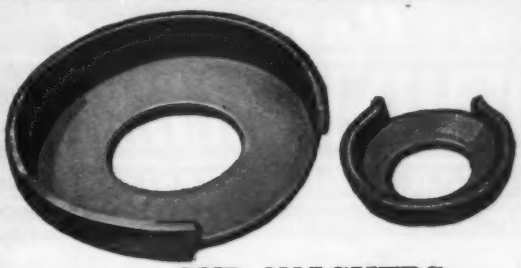

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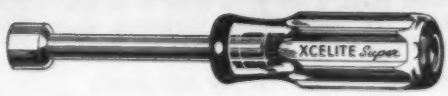

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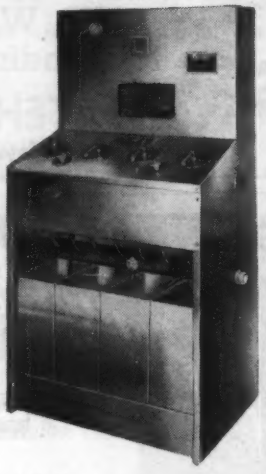

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This volume also contains a mathematical appendix on Bessel functions and complex integration and an extensive chronologically arranged f-m bibliography of nearly 300 items running from 1922 to 1947.

To anyone interested in f-m and having a reasonable working knowledge of German, this book will prove a useful tool.—JOHN H. BOSE, *Columbia University, New York, N. Y.*

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PUBLISHED BY HOWARD W. SAMS & CO., *Indianapolis, Indiana, October 1947, approx. 400 pages, $4.95.*

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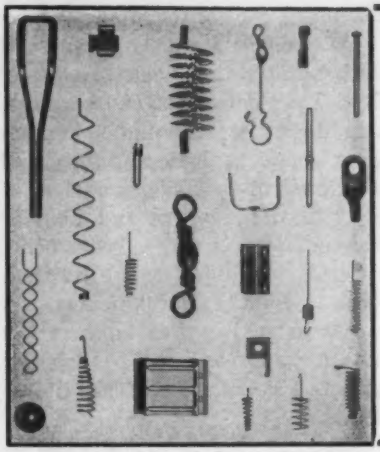

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GENERAL ELECTRIC

to general types of automatic record changers and types of motor drive systems associated with them, are gems of technical organization and writing on a complicated subject. The various methods used for record support, record selection, pickup arm handling, determining set-down point, and tripping are described clearly, concisely, and logically so that one gets a satisfying complete picture of how these mechanisms are supposed to work.

Going far beyond the usual manufacturer's service manual, this book with its clear-cut instructions and illustrations truly offers an education in the latest styles of mechanical gadgetry for converting recordings to sound automatically.—J.M.

Mathematics for Radio Engineers

By LEONARD MAUTNER, *Research Engineer, Allen B. DuMont Labs. Pitman Publishing Corp., New York*, 1947, 327 *pages*, $5.00.

WRITTEN for engineers who have lost facility in handling mathematics and those who, although proficient in radio techniques, have never acquired a command of mathematics, this book briefly reviews the elements of enumeration, then describes trigonometric relations, complex algebra, differential and integral calculus, solution of differential equations, and Fourier series. In scope the book penetrates further into the subject than books intended for technicians, but is less extensive than engineering texts used in colleges. As such it bridges a gap in math-book literature.

Although this is a mathematics book, material is presented in its relation to typical basic problems of radio rather than as abstract mathematical methods. The presentation thus makes the subject more tangible than usual works of this calibre. Because of the choice of only those phases of mathematics frequently encountered in solving radio circuit problems, and the close correlation of the mathematics with radio, engineers will find this book a ready key to mathematics in their work. Answers are included for the problems at the ends of the chapters so that the book is useful

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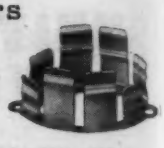

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For notes on horn loading, see August/47 page 214.

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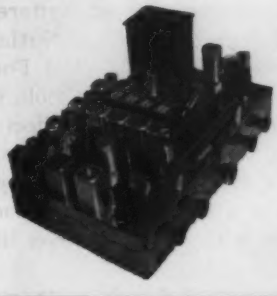

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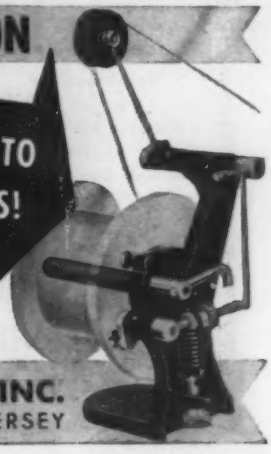

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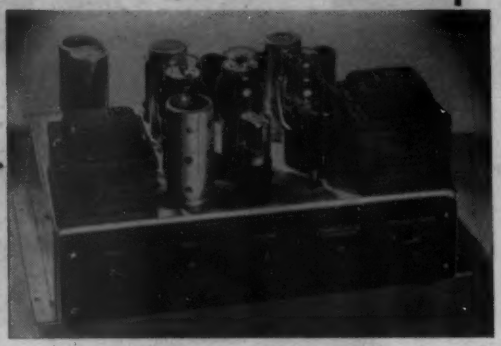

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for home study. The work is also suited for trade schools which believe that radio technicians, to advance in their work, should be well grounded in mathematics.—F. R.

• • •

Books Received for Review

ELECTRETS. By Thomas A. Dickinson. Plastics Research Co., Alhambra, Calif., 1948, 32 pages, $2.50. Pocket-size monograph dealing with properties, applications, and manufacturing techniques of electrets, defined as dielectric bodies that retain an electric field after the applied voltage is removed. Purpose of book is to show that expensive permanent magnets for electronic equipment can be replaced with polarized dielectrics such as plastic or ceramic units.

UNDERSTANDING VECTORS AND PHASE. By John F. Rider and Seymour D. Uslan. John F. Rider Publisher, Inc., New York, N. Y., 1947, 153 pages, 99 cents. Pocket-size paper-cover book for men lacking an engineering background, to help them understand radio-electronic articles and books written at the engineering level. Eight chapters explain vectors and give examples of their use in radio circuits.

SPI HANDBOOK. Society of the Plastics Industry, 295 Madison, New York, N. Y., 1947, 451 pages, $7.50. Though prepared by a committee of some 300 authorities in the field as a handbook for molders and fabricators of plastics parts, much of the contents is of importance also to the ultimate user. Chapter coverage includes design of molded articles, use of inserts, cementing and assembly of plastics, machining and finishing and recommended practices for fabricating laminated plastics.

INDUSTRIAL APPLICATIONS OF INFRARED. By James D. Hall, Advisory Engineer, Lamp Division, Westinghouse Electric Corp. McGraw-Hill Book Co., New York, 1947, 201 pages, $3.50. What would have been one chapter of a book on heating several years ago has now justified expansion by inclusion of numerous specific examples of use. Chapters discuss infrared heat, equipment, installation, and applications of infrared lamps for a variety of processes requiring surface application of low-level heat.

PERPETUAL TROUBLE SHOOTER'S MANUAL, VOL. XV. John F. Rider, Publ., Inc., New York, N. Y., 1947, over 1,200 pages, plus 181-page HOW IT WORKS supplement, $18.00. This series constitutes a tool for radio servicemen and a guide to current radio practice for set designers. Where original manufacturers' diagrams are not clear, supplementary diagrams have been added. The paper-bound supplement covers new electrical and mechanical features of receivers and has an index to the manual. Among subjects included are the double superhet, superhet oscillators, r-f coupling, feedback, phase inversion, gimmicks, and f-m circuits.

THE ABC OF ELECTRONICS. By E. B. Watton. Percival Marshall & Co. Ltd., 23, Great Queen St., London, W. C. 2, 1947, 133 pages, 7/6. Bird's-eye view of modern industrial electronics, with one chapter on communications, combining technical explanations of operating principles with popular descriptions of such applications as the Radarange, snooperscope, speaking clock, and tube train counter. Well illustrated.

TABLE OF THE BESSEL FUNCTIONS $J^0(z)$ AND $J^1(z)$ FOR COMPLEX ARGUMENTS, 2nd ed. Mathematical Tables Project, National Bureau of Standards, Columbia University Press, New York, 1947, 403 pages, $7.50. A clarification in labeling graphs has been made in this edition. No errors in the tables having been reported, they have been reproduced from the original plates.

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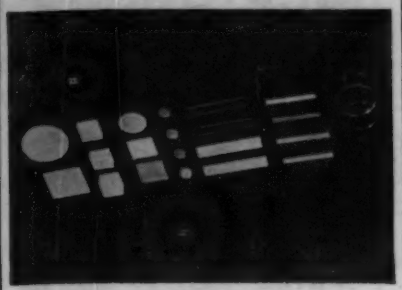

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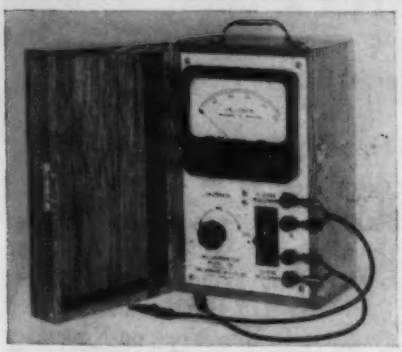

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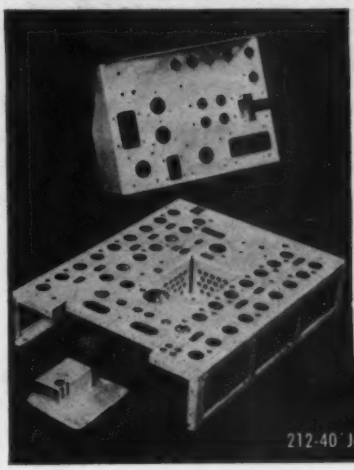

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Reference Sheet Data

DEAR SIRS:

METICULOUS readers who wish to use the graph in the Reference Sheet, Efficiency of Inductive Coupling, page 138, December ELECTRONICS, may make the following additions.

In the formula, subscripts can be added to Q in both places where it appears. In the lefthand graph, all values of Q, are identical with the values given in the righthand graph. The primary resistor in the diagram can be indicated as R_p. The ordinates of both parts of the graph are, of course, k_2Q_p.

A. C. HUDSON
National Research Laboratories
Ottawa, Ontario

Hartley Law

DEAR SIRS:

ELECTRONICS is to be complimented upon the fast and clear reporting of the IRE symposium regarding the revision of Hartley's Law which was held in New York on November 12, 1947.

Since so little has appeared on this subject treating it in a general way, I feel that one correction is necessary for the historians. The first statement of the new law to appear in print was, to my knowledge, in the Quarterly Progress Report of the Research Laboratory for Electronics of the Massachusetts Institute of Technology, dated 15 April 1947, which receives an extensive circulation among the military services. ELECTRONICS can probably lay claim to first publica-

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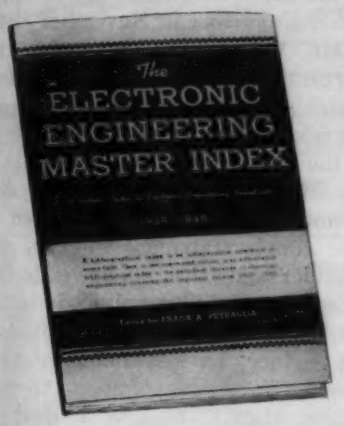

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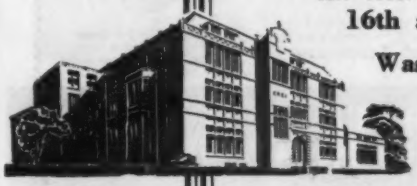

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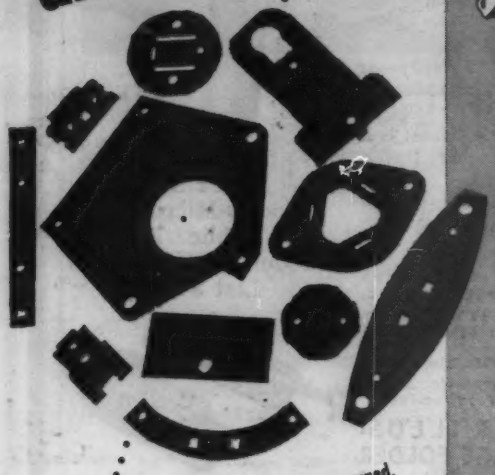

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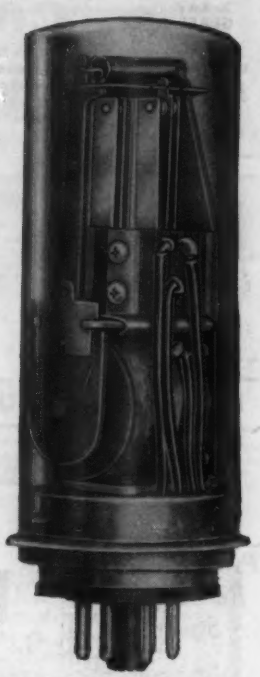

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tion in a magazine of general interest and circulation.

Another historical step in this field should be credited to Dr. D. Gabor of the British Thomson-Houston Company Research Laboratory in his article entitled "Theory of Communication" in the *Journal of the Institution of (British) Electrical Engineers* in November 1946.

Mr. Wheeler made a very important point in his discussion which appears to have been lost or overshadowed by the proceedings of the evening. He pointed out that uncertainty of signal location due to noise should not be dismissed in that simple statement wherein one considers only the rms power in the noise or signal plus noise. It is becoming increasingly important that the engineer have available in engineering form (as opposed to the mathematical), means of dealing with these uncertainty relationships.

In many systems it may be possible to take a calculated risk in operating at low signal-noise ratios where this uncertainty sphere is more diffuse. In such systems, the engineer must have available the probabilities that noise may be mistaken for signals or that signals be missed completely. Mr. Wheeler also pointed out that in many simple receiving systems the noise power N was related to the bandwidth of the system W by well-known relations.

Dr. Shannon also discussed briefly the significance of distortion as a warping of the space which might in theory be rewarped by another operation to achieve its original form. This is also a significant point as it relates Hartley's discussion of intersymbol interference caused by circuit decay or distortion to Dr. Shannon's remarks.

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MR. MAISEL of Portland, Ore. (Backtalk, Jan. 1948) says "One problem . . . here in the remote

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west is the lack of the latest available components . . . a challenge to us local fellows . . . ".

The implication is that anyone who lives east of Chicago has only to walk to the corner radio store to find shelves crammed with electronic rarities — subminiature tubes, varistors, butterfly circuits, and of course button capacitors.

I have been doing circuit development in a large Government laboratory in Washington, D. C. for several years, and some time before that lived in Los Angeles. Radio parts are definitely less available here than they were in Los Angeles. Washington has several good parts jobbers, but their size and stocks are modest and their locations inconvenient. For that matter, I have seen plenty of similar places in New York and Chicago that weren't so hot either.

Personally, I buy parts by mail order. The Laboratory gets components from sources all over the country. Unusual items are often ordered directly from the manufacturer.

Any material that is not regularly bought by lots of radio servicemen and amateurs is likely to be pretty scarce at parts dealers in any city, no matter where it is. A year ago the mail order houses seemed to be habitually out of stock on half or more of the things I ordered (even as were the local dealers), but recently I have had much better luck. The greater distances in the west make for higher parcel post charges, of course; but gasoline, bus fare, and shoe leather don't come for free either.

On another subject, Mr. Meredith's letter (Backtalk, Jan. 1948) shows that he is a most unusual patent attorney. In my four years as a patent examiner I encountered few attorneys who didn't use "electron discharge device" when they meant *tube*. One reason for patent lingo being what it is, is the necessity for broad language to avoid its being interpreted later in a restrictive sense. The other reason is that it is harder to write up a case thoughtfully than it is to just let the words roll out.

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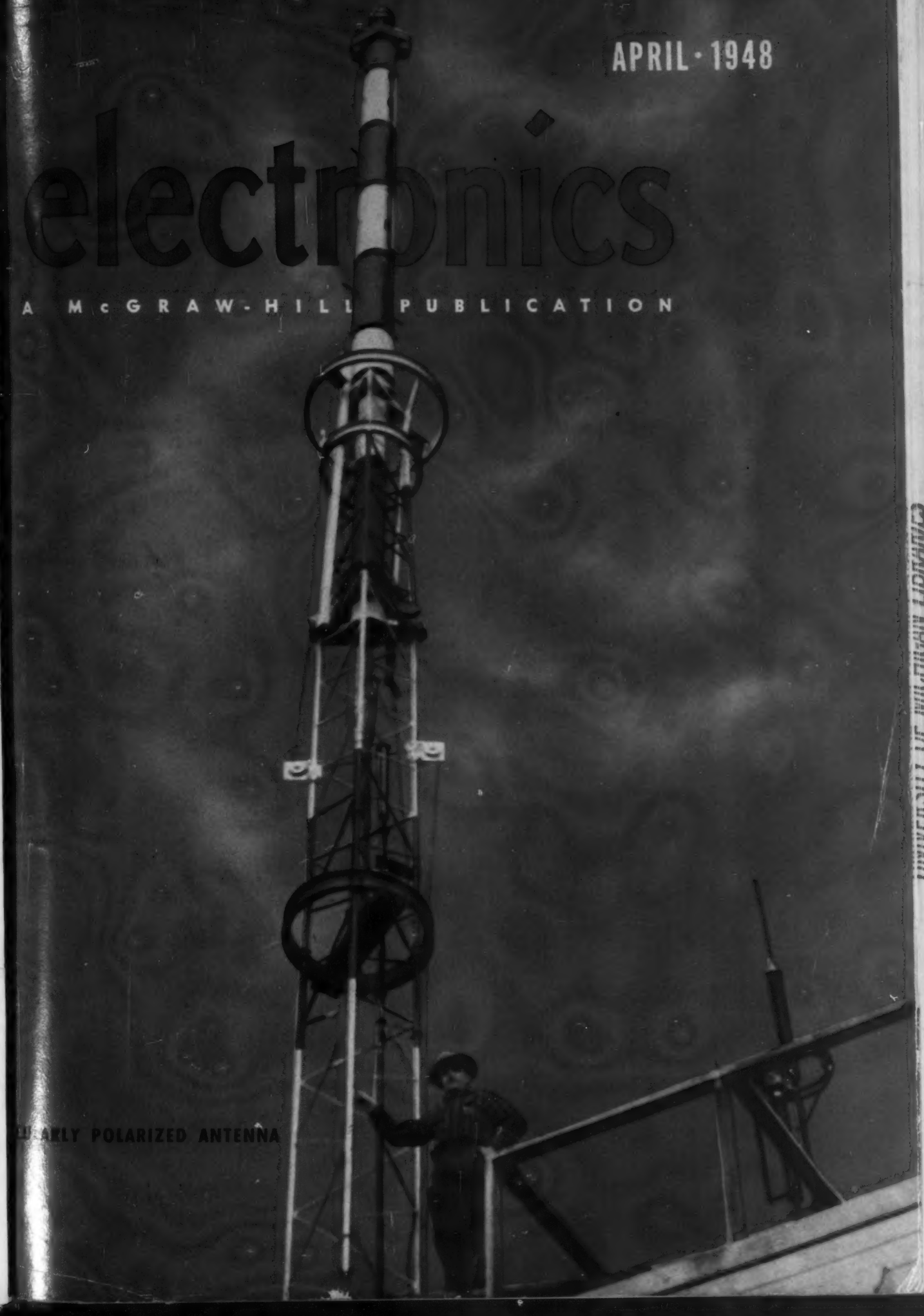

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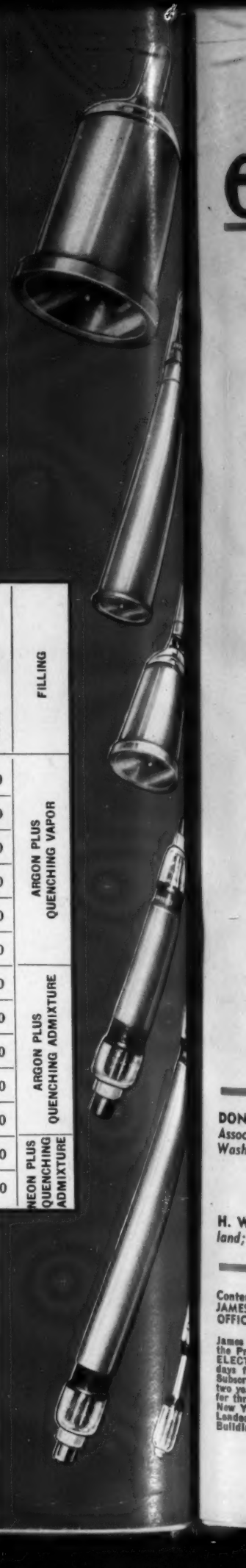

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COPPER CATHODE	1E GAMMA	$4\frac{3}{16}$x$\frac{3}{4}$	$1\frac{1}{16}$x$\frac{1}{2}$x.020	——	——	−20 to +100	300	2% to 5%	1.5	10	99%	10^8	1150	ARGON PLUS QUENCHING VAPOR
	1M GAMMA	$4\frac{3}{16}$x$\frac{3}{4}$	$1\frac{1}{16}$x$\frac{1}{2}$x.020	——	——	0 to +100	500	10%	1 5	2	20%	10^{10}	1400	
	4E GAMMA	$7\frac{15}{16}$x$1\frac{3}{16}$	3x1x$\frac{1}{16}$	——	——	−20 to +100	300	2% to 5%	2.4	90	99%	10^8	1150	
	4M GAMMA	$7\frac{15}{16}$x$1\frac{3}{16}$	3x1x$\frac{1}{16}$	——	——	0 to +100	500	10%	2.4	20	20%	10^{10}	1400	
	10E GAMMA	13x$1\frac{3}{16}$	8x1x$\frac{1}{16}$	——	——	−20 to +100	300	2% to 5%	3.6	200	99%	10^8	1150	
	10M GAMMA	13x$1\frac{3}{16}$	8x1x$\frac{1}{16}$	——	——	0 to +100	500	10%	3.6	40	20%	10^{10}	1400	
STAINLESS STEEL CATHODE (END MICA WINDOW)	100C BETA	$3\frac{3}{4}$x$1\frac{5}{16}$	$1\frac{1}{2}$x$1\frac{3}{16}$x$\frac{3}{32}$	.0005	$1\frac{3}{32}$	−70 to +100	300	2% to 5%	1.0	50	——	*Unlimited by Use	1200	ARGON PLUS QUENCHING ADMIXTURE
	120C BETA	$5\frac{1}{4}$x$2\frac{3}{8}$	$2\frac{11}{16}$x2x$\frac{5}{64}$	.0008	$1\frac{29}{32}$	−70 to +100	300	2% to 5%	1.0	250	——		1200	
	150C BETA, GAMMA and X-RAY	$6\frac{7}{16}$x1	4x$\frac{7}{8}$x.047	.0005	$\frac{25}{32}$	−70 to +100	300	5%	2.4	62	80%		1200	
	150M BETA, GAMMA and X-RAY	$6\frac{7}{16}$x1	4x$\frac{7}{8}$x.047	.0005	$\frac{25}{32}$	0 to +100	500	10%	2 4	15	20%	10^{10}	1400	
	200C ALPHA	$3\frac{3}{4}$x$1\frac{5}{16}$	$1\frac{1}{2}$x$1\frac{3}{16}$x$\frac{3}{32}$	.0002	$1\frac{3}{32}$	−70 to +100	300	2% to 5%	1.0	50	——	*Unlimited by Use	1200	
	100N BETA	$3\frac{3}{4}$x$1\frac{5}{16}$	$1\frac{1}{2}$x$1\frac{3}{16}$x$\frac{3}{32}$	.0005	$1\frac{3}{32}$	−70 to +100	100	5%	1.0	50	80%		450	NEON PLUS QUENCHING ADMIXTURE
	150N BETA and GAMMA	$6\frac{7}{16}$x1	4x$\frac{7}{8}$x.047	.0005	$\frac{25}{32}$	−70 to +100	100	5%	2.4	62	80%		450	

NOTE: All tubes listed have a dead time of 200 microseconds

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Combination of slotted and dipole sections designed by Carl E. Smith of United Broadcasting Company (Photo by Harry Miller)

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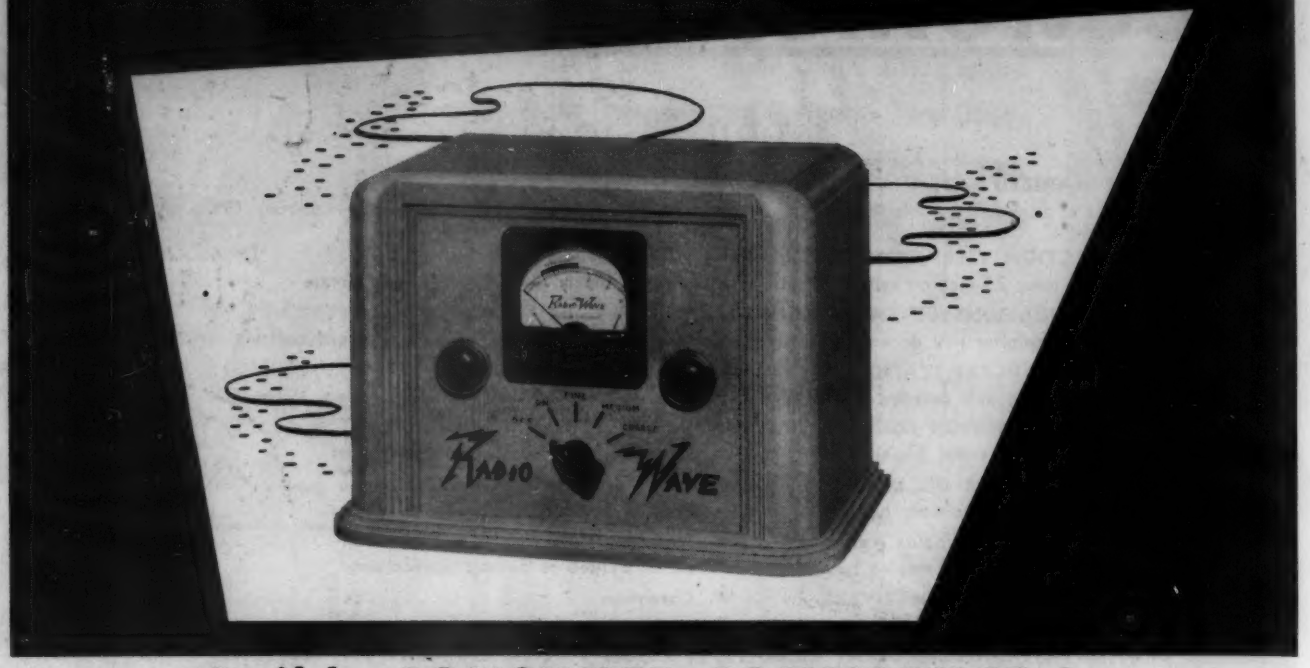

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